

DSIR AND FOC
FIRE RESEARCH
ORGANIZATION
REFERENCE LIBRARY
No. A12.P30(2)



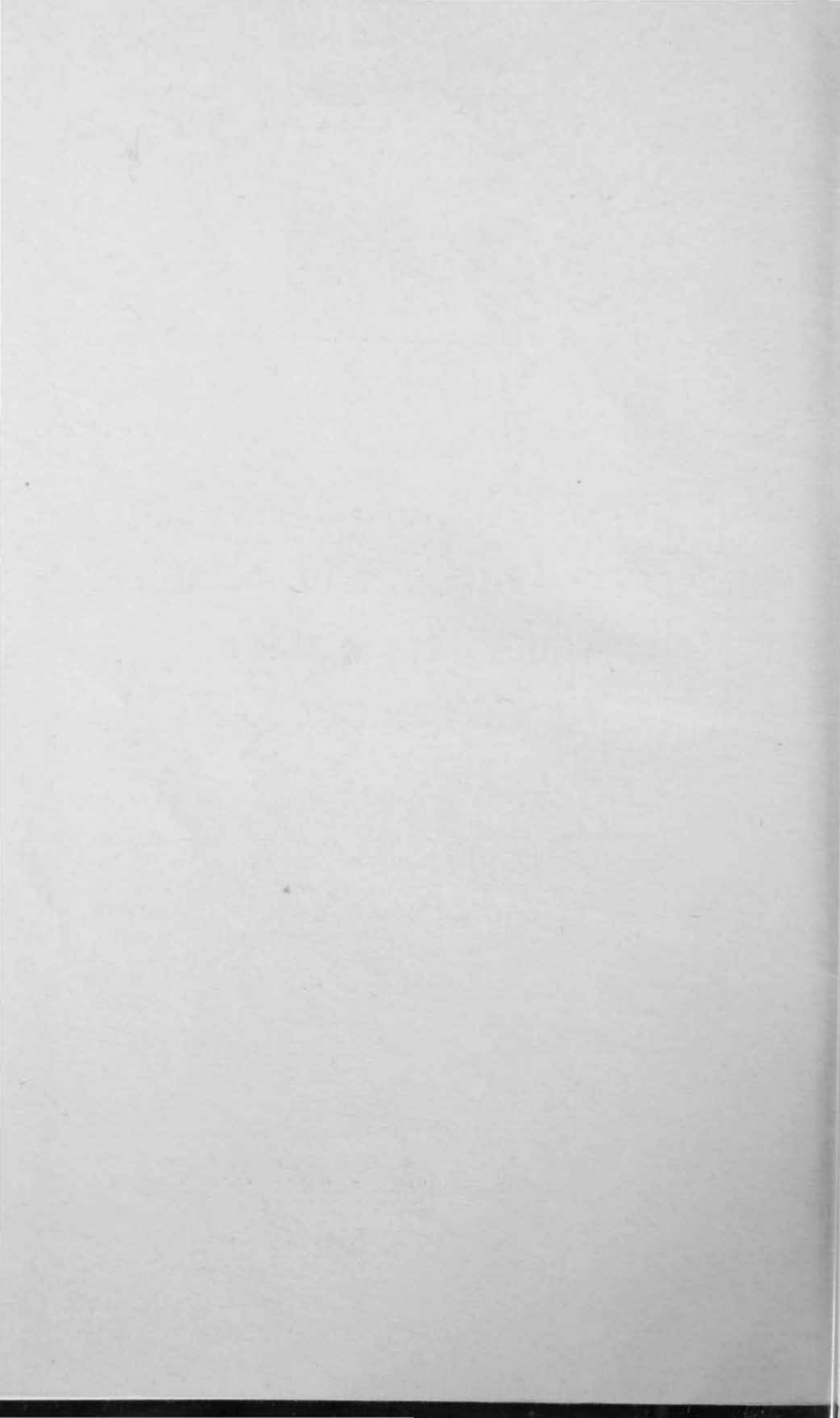
HOME OFFICE

**Report on Explosion and Fire
at Regent Oil Co. Ltd. premises
Avonmouth, Bristol
on 7th September 1951**

LONDON : HER MAJESTY'S STATIONERY OFFICE

1952

PRICE 2s. 0d. NET



HOME OFFICE

REPORT ON
EXPLOSION AND FIRE AT
REGENT OIL CO. LTD. PREMISES
ROYAL EDWARD DOCK
AVONMOUTH, BRISTOL
ON 7th SEPTEMBER,
1951

by

H. E. WATTS, C.B., M.B.E., G.M., Ph.D., B.Sc. F.R.I.C.,

H.M. Chief Inspector of Explosives

LONDON: HER MAJESTY'S STATIONERY OFFICE

1952

REPORT ON
EXPLORATION AND MINING
ACTIVITY IN THE
ROYAL ALBERTA
PROVINCE
ON THE 21st FEBRUARY
1921

By
J. H. M. J. VAN DER WERF

HOME OFFICE,

LONDON, S.W.1.

1st December, 1951

*To the Right Honourable the Secretary of State
for the Home Department.*

SIR,

I have the honour to report that in obedience to the Order made under Section 14 of the Petroleum (Consolidation) Act, 1928, and dated the 7th September, 1951, I have held an Inquiry into the causes of and circumstances attending the fatal accident which occurred on the 6th September, 1951, at the premises of the Regent Oil Company, Limited, at the Royal Edward Dock, Avonmouth, Bristol.

By this accident two lives were lost, namely:—

Royston Douglas Hyett, aged 33 years, married, and

Arthur Charles Baggs, aged 38 years, married.

I also attended the adjourned Inquest, held at the Coroner's Court, Bristol, on the 5th November, 1951, by Mr. A. E. Barker, Coroner for Bristol, when the Jury returned a verdict of death by misadventure due to an explosion, the cause for which was unknown.

Description of the premises

The premises of the Regent Oil Company, Limited, at the Royal Edward Dock, in which the accident occurred are known as No. 1 Depot and covered an area of about seven acres situated on the bank of the river Severn. This depot was licensed by the Council of the City and County of Bristol as the Harbour Authority, for the storage of 12,000,000 gallons of petroleum spirit. There was another depot called No. 2 Depot in the vicinity and the two depots together were capable of storing 70,000 tons of petroleum in over-ground steel tanks. No. 2 Depot was licensed for the storage of 5,300,000 gallons of petroleum spirit. In No. 1 Depot groups of tanks were surrounded by a tapered reinforced concrete wall about 4 inches thick at the top. This wall served as a bund to prevent the outflow of petroleum in the event of the contents of the tanks escaping. The bund in which the fire occurred is that shown on the plan in Appendix I in which Tanks Nos. 1, 2, 3, 4, 13, 14, 5, 6, 7, 8, 9, 10, 11, 12, 27 and 28 are situated. There was a central pump house adjoining this bund situated in its own compound, and also surrounded by a tapered reinforced concrete wall. Tankers were discharged from a jetty by means of a 10 inch diameter earthed pipe-line which ran from the jetty to the depot for a distance of about 3,250 feet. Separate pipe-lines were used for the different products.

Circumstances leading up to the fire

At about 11.15 p.m. on the 5th September, 1951, the tanker "Fort Christina"* belonging to the Overseas Tankship (United Kingdom) Limited arrived and tied up at No. 5 berth at the oil basin, Royal Edward Dock. The cargo consisted of about 13,000 tons of motor spirit and 2,050 tons

* Now known as Caltex Glasgow.

of gas oil. The arrangement of the tank compartments in the tanker were stated to be as follows:—

No. 1 tank consisted of port and starboard tank compartments.

Nos. 2-9 tanks inclusive.—Each consisted of port, centre and starboard tank compartments.

All the compartments of Tanks Nos. 1 to 8 inclusive were loaded with motor spirit, and the three compartments of No. 9 tank were loaded with gas oil on the 14th and 15th August at Bahrein. The flash point of the gas oil in tank No. 9, as determined at Bahrein, was stated to have been 174° F.

On the arrival of the tanker Mr. Illingworth, the Assistant Superintendent of the depot, collected the ship's papers in the usual way when he met Captain Watson, the Port Captain of Overseas Tankship (United Kingdom) Limited, together with the ship's master. It was understood that Captain Watson wished to see Mr. Illingworth as, on about the 18th August the motor spirit in No. 8 starboard tank overflowed, but eventually the level in No. 8 starboard tank was counter-balanced by the level of the gas oil in No. 9 starboard tank, and it was feared that there had been some contamination between the gas oil and the motor spirit of the cargo. Accordingly he wished that the contents of the sections of the ship involved should be carefully tested. The Captains stated that in their opinion the contents of Tanks Nos. 1 to 7 inclusive were all right, but they feared that contamination had taken place between the transverse bulkhead separating tanks 8 and 9, but they did not know to what extent. Mr. Illingworth arranged for the tester, Mr. Davis, to test personally the samples taken from each of the compartments of Tanks 8 and 9 and samples were also taken from Tanks 1 to 7. The results of these tests showed that the only tank to be affected was No. 8 starboard tank and this tank was found to be seriously contaminated with gas oil. The contents of all the other tanks were within their specification. Details of the examination of the samples taken from No. 8 starboard tank and an average sample from tanks 1 to 7 inclusive are contained in Appendix 2.

The tanker was originally destined to discharge her cargo at Dublin but owing to the strike at that port she was diverted to Avonmouth.

The Shell Company were to take 4,000 tons of motor spirit and 1,000 tons of gas oil from the tanker, and consequently this Company also took samples from the contents of each of the compartments of tanks Nos. 8 and 9, and their final decision was in agreement with that arrived at by the Regent Company, namely that No. 8 starboard was the only tank which was contaminated.

In view of the fact that the motor spirit in No. 3 tank was fit for discharge arrangements were made to start pumping with the ship's pumps from the tank into shore tanks 32 and "S" in the Regent Company's Depot No. 2 at about 1.10 a.m. on the 6th September. This was done to avoid holding up the ship and this operation was carried on till later in the morning. Neither of these two shore tanks was in any way affected by the subsequent fire. At about 9.15 a.m. on the 6th September, after further discussions between Mr. Illingworth and the two Captains and Mate, it was decided to pump out No. 8 starboard and No. 8 port tanks as contaminated motor spirit into No. 3 shore tank in the Regent Company's Depot No. 1. This shore tank already contained about 1,150 tons of motor spirit and was the smallest tank available. The two wing tanks were to be pumped out together to trim the vessel.

At the same time No. 9 starboard and port tanks were to be pumped out into No. 1 shore tank in the Regent Company's Depot No. 1, and these pumping operations were to be simultaneous, but the discharge from No. 8 wing tanks was to be slightly ahead of the discharge from No. 9 wing tanks so that the level of the motor spirit in No. 8 tanks should be about two feet below the level of the gas oil in No. 9 tanks. In this way it was thought any more contamination would result in further contamination of the motor spirit instead of contamination of the gas oil.

Before this operation was commenced Mr. Illingworth obtained agreement of Mr. Cumming at the head office of the Company. Meanwhile they were proceeding with pumping operations from tanks 1 to 7 into shore tanks 32 and "S" in their No. 2 Depot. During pumping operations the tanker was having trouble with the pumps and an engineer had to go down into the pump room to start and stop the motors.

At about 11 a.m. the pumping of motor spirit into shore tanks 32 and "S" was stopped, and the valves on these two tanks were closed, and they started pumping No. 8 wing tanks into No. 3 shore tank.

After about 15 minutes they started pumping the gas oil from No. 9 wing tanks into No. 1 shore tank (about 6,900 water tons capacity). Directly after starting to pump the gas oil Mr. Illingworth drew a sample of gas oil from the pipe line at the jetty from the dead leg. The pipe connection at the jetty was in the form of a "Y". One limb of the "Y" was connected to the tanker, and the other limb was blanked off. The latter limb is the dead leg. Separate "Y" connections are kept for each product. The sample flashed below 73° F. A second sample was drawn which flashed at 84° F. The pumping of the gas oil was stopped immediately. This took place at approximately 11.35 a.m.

By this time about 120 tons of gas oil had already been pumped into No. 1 shore tank. Meanwhile the pumping of the motor spirit from No. 8 wing tanks continued.

A check sample was then taken from No. 1 shore tank and it was found that the gas oil in this tank was not affected. Mr. Davis asked Hyett for a top sample from shore tank No. 1 and this sample had a flash point of 160° F. The pumping of the motor spirit from No. 8 wing tank was completed at about 2 p.m. Just before finishing this operation it was decided to pump out the gas oil again, and another sample was drawn from the "dead leg" of the gas oil line and this flashed at 150° F. Arrangements were then made to pump about 75 tons of gas oil into No. 13 shore tank in order to clear the pipe line and Hyett was instructed accordingly. The shore tank No. 13 which was 18 feet high and 20 feet in diameter contained about 40 tons of gas oil which would be equivalent to a dip of about 5 ft. and Hyett was told to take gas oil from the tanker into this shore tank until the dip was 15 ft. and that if the ship had not stopped pumping by the time this dip had been reached, he was to divert the gas oil into shore tank No. 1. Hyett was told to go on the top of shore tank No. 13 and watch the oil in through the manhole, as the ship might possibly be unreliable for speed and it might come up quickly. This procedure was adopted because Mr. Illingworth and Mr. Davis thought that something had been trapped in the gas oil line and that the last sample was not a true one, and they wanted to avoid pumping contaminated material into No. 1 shore tank. Before they started pumping the gas oil into No. 13 shore tank Mr. Illingworth remained on the tanker and saw that the pressure on the gas

oil pipe line was brought up to 25 lbs. per square inch instead of the usual pressure of 75 lbs. per square inch. It was thought that at this pressure the gas oil would be pumped through at a rate of about 150 tons per hour. They started to pump the gas oil at about 2.30 p.m. and about two minutes after this Mr. Illingworth drew a further sample of gas oil from the "live leg" and took it to Mr. Davis at the laboratory for testing (the "live leg" is the limb connected to the tanker).

At 2.30 p.m. Mr. Davis took gallon samples of No. 9 port, centre and starboard compartments for examination and the results were as follows:—

Tank	No. 9 Port	No. 9 Centre	No. 9 Starboard
Specific gravity ...	0.8340	0.8340	0.8340
Flash Point °F. ...	166°	158°	162°

The line sample of gas oil which was taken by Mr. Illingworth was being tested by Mr. Davis, and the temperature of 104° F. had been reached, without flashing, when an explosion and fire occurred at the shore tank No. 13. The fire was observed to take place at 2.47 p.m.

In the meantime after the No. 8 wing tanks had been pumped out into shore tank No. 3, they proceeded with the general discharge of the motor spirit cargo from No. 6 tank and this was being pumped into shore tanks Nos. 32, 3 and "S".

Baggs was in charge of loading motor spirit from shore tank No. 2 into barges for Cardiff, and at the time of the accident spirit was being pumped into the barge "Ribblesdale" by Vicker who relieved Baggs just after 2 p.m.

Vicker was standing between the pump house and shore tank No. 19 at about 2.40 p.m. in full view of the shore tanks Nos. 13 and 14. He stated that he saw Hyett and Baggs on the top of shore tank No. 14. Hyett was dipping the tank and Baggs was talking to him. He went back into the pump house to see if the pumps were running correctly and then came out again. When he came back to the same place from which he had seen the two men before, he noticed that Baggs had moved from the top of the tank and was standing on the ladder running between the two shore tanks Nos. 13 and 14. Hyett was in the same place as before still dipping. The next thing Vicker saw was a ring of fire round the top of shore tank No. 14 and Hyett was lifted up off the tank towards the railway siding. He returned to the pump house, shut the pumps down and closed the valves which were in use for supplying motor spirit to the Barge "Ribblesdale", but he omitted to close the suction valve on No. 2 shore tank. No other pumps were working. It seems possible that Vickers was mistaken in thinking that Hyett was on shore tank No. 14. The evidence of all the witnesses was to the effect that he was on shore tank No. 13.

Potter, a jetty hand, was on duty at the jetty to which the tanker "Fort Christina" was moored and between 2.45 and 2.50 p.m. he heard an explosion and saw smoke and flames. He shouted to the tanker crew to stop their pumps as he thought that the fire and explosion had occurred in one of the tanks at the Regent Company's Depot. The ship's pumps were shut down and all the jetty valves and intermediate valves from the jetty to the depot were closed. The Chief Clerk, Mr. Ansell, phoned for the Fire Brigade but he was told that the fire had been reported two seconds earlier.

Progress of the Fire

The fire and explosion started in No. 13 tank and the flames spread with great rapidity and reached the roofs of the tanks Nos. 5 and 6 which contained aviation spirit and motor spirit respectively. The flames were fanned by a northerly wind which was blowing at about 6 miles per hour.

Within about 25 minutes the horizontal tanks 7, 8, 9, 10, 11, 12, 27 and 28 containing benzole aviation spirit and motor spirit were involved. The ends of these tanks were blown out and their contents dispersed into the compound. The suction valve on No. 6 tank was open and the contents of this tank added to the conflagration. The flames then spread towards tanks Nos. 4, 3 and 2. Flames ran down the irrigation ditches towards the river and down towards tank No. 1. The flames came over the bund wall and set fire to the sleeper stop blocks on the siding in which there were three rail tank wagons loaded with aviation spirit.

At the time of the outbreak of the fire three road tank wagons were in process of being filled with spirit from the horizontal tanks and tank No. 6. These road tank wagons were got away safely and the rail tank wagons were also removed to safety.

The Depot fire fighters went into action quickly and ran two depot hoses out into the yard. There was insufficient water pressure to reach the tops of the tanks as water was being used to cool the tanks in other depots. The depot foam hopper was brought into action before the overhead horizontal tanks were involved in the fire, but the men were ordered out of the yard by the Fire Brigade. Subsequently O'Neill played foam on to tanks 3 and 4, and beat the flames back to the steps near tank 13. The fire in this part of the compound was then under control with a blanket of foam over it. This was done to try and confine the fire to tanks 5 and 6.

The 8 inch salt water mains were being used for cooling tanks in other depots, but it was between 4 and 4.30 p.m. before any serious cooling of tanks took place.

Shore tanks Nos. 3 and 4 were soon involved and No. 3 collapsed at about 4 a.m. on the 7th September.

There was a general conflagration in the bund containing the tanks 1, 2, 3, 4, 5, 6, etc., owing to the contents of the tanks 6, 7, 8, 9, 10, 11, 12, 27 and 28 flowing towards tanks 4, 3, 2, and 1, and subsequently No. 2 added about 3,000 tons of motor spirit to the fire. The pipe line to this tank was fractured near this tank and No. 3 tank. The fire lasted about 38 hours, and when it was finally extinguished there was still a layer of several inches of motor spirit floating on about 18 inches of water in the bund.

When the level of the water in the bund was lowered it was found that the shore tank No. 2 continued to discharge motor spirit into the bund until the tank outlet was plugged.

Result of the fire

When the water and motor spirit was finally drained from the bund it was found that all the pipe lines within the bund running beside the tanks 1, 2, 3 and 4 had all been fractured. The vertical tanks Nos. 5, 6, 16 and 1 although damaged were still standing; tanks Nos. 13, 4 and 3 had collapsed and tank No. 2 had partially collapsed. The horizontal tanks 7, 8, 9, 10, 11, 12, 27 and 28 had their ends blown out.

Human remains were found, inside tank No. 13, and also a few feet forward of this tank towards No. 4 tank.

One of the large vertical tanks (No. 3) was floated 4 feet from its seating.

The reinforced concrete bund wall was damaged in several places.

The total quantity of petroleum involved in the fire amounted to about 7,000 tons.

The following table shows the dimensions of the tanks in the bund in which the fire occurred together with the nature and quantity of the products in the tanks before and after the fire, and the condition of the suction valves on the tanks.

Tank No.	Dimensions of tank		Nature of Product contained in tank	Quantity of Product in tank		Condition of Suction Valve during the fire
	Diameter	Height		Before the fire	After the fire	
	Feet	Feet		Tons	Tons	
No. 1 ...	95	35	Gas Oil ...	4,617	4,613	Closed
No. 2 ...	95	35	Motor Spirit ...	4,131	Nil	Open
No. 3 ...	70	35	Motor Spirit ...	1,060	Nil	Closed
No. 4 ...	65	35	Motor Spirit ...	1,354	Nil	Closed
No. 5 ...	32	25	Aviation Spirit ...	302	225	Closed
No. 6 ...	25	25	Motor Spirit ...	158	Nil	Open
No. 7 ...	9	30 long	Motor Spirit ...			Open
No. 27 ...	9	15 long	Motor Spirit ...			Open
No. 8 ...	Three Compartment horizontal tank 9 30 long		Aviation Spirit ...	1.2	Nil	Not known
No. 9 ...			Aviation Spirit ...	15.7	Nil	Not known
No. 10 ...	Two Compartment horizontal tank		Aviation Spirit ...			Not known
No. 11 ...			Benzole ...	22	Nil	Open
No. 12 ...	9	30 long	Benzole ...			Open
No. 13 ...	20	18	Gas Oil ...	41	Nil	Closed
No. 14 ...	20	18	Gas Oil ...	36	Nil	Closed
No. 28 ...	9	15 long	Motor Spirit (Benzole mixture).	0.7	Nil	Closed

Note:

The tanks Nos. 1, 2, 3, 4, 5, 6, 13 and 14 were vertical tanks, and tanks Nos. 8, 9 and 10 consisted of three compartments of a horizontal tank 9 feet in diameter and 30 feet long, tanks Nos. 27 and 28 consisted of two compartments of a horizontal tank 9 feet in diameter and 30 feet long and tank No. 7 consisted of a horizontal tank 9 feet in diameter and 30 feet long.

Cause of the explosion

In order to bring about the explosion and fire two conditions are necessary, namely (1) the presence of an explosive atmosphere in tank No. 13 and (2) some means of igniting this explosive atmosphere in tank No. 13.

(1) The presence of an explosive atmosphere in tank No. 13

The temperature of the contents of tank No. 13 prior to the explosion was not as high as the flash point of gas oil (about 160° F.); this is confirmed by the Director of the Meteorological Office who stated that from the observations made at Filton on the 6th September, 1951, the maximum temperature during the period 6-18 hours was 71° F. The details supplied by the Meteorological Office are contained in Appendix 3 attached. The flash point of the gas oil in tank No. 13 before pumping operations began was 170° F. Accordingly, it is quite clear that it was not gas oil vapour which caused the explosion, as the temperature of the flash point of gas oil had not been attained.

It therefore follows that some other ignitable mixture must have been present in this tank. One possibility appears to be that petroleum spirit may have been introduced into the tank by the pumping operations from the "Fort Christina".

Assuming that petroleum spirit had been introduced into this tank, and also that the rate of pumping from the ship had been kept constant at about 150 tons per hour, the height of the liquid in tank No. 13 at the time of the explosion would have risen to 10 feet, thus leaving a free space in the tank of about 8 feet. Under these conditions it would be necessary for about $1\frac{1}{2}$ gallons of petroleum spirit to have been present in the form of vapour to render the free space explosive. If, however, the rate of pumping was faster, the free space in tank No. 13 would be reduced, and therefore the quantity of petroleum spirit required to render the free space explosive would be correspondingly reduced. Furthermore if petroleum spirit vapour were present in tank No. 13 the conditions produced by pumping operations from the tanker, by continuously reducing the free space in tank No. 13, would cause the atmosphere in that tank to pass through all the conditions from a weak non-explosive to an explosive and then a rich non-explosive mixture of petroleum spirit vapour in air, owing to the continuous displacement of the air in the free space above the liquid in tank No. 13. The condition for an explosive mixture is that the percentage of petroleum spirit vapour in the free space should be between $1\frac{1}{2}$ to 6 per cent.

The question then arises as to how the petroleum spirit was introduced into tank No. 13 as this tank was used for gas oil.

At Bahrein the ullage of No. 8 starboard tank was 4 feet at 97° F. and the ullage of No. 9 starboard tank was 4 feet $2\frac{1}{2}$ inches at 108° F.

During the voyage from Bahrein to this country it is quite clear that there was a leak between tanks Nos. 8 and 9 in the tanker "Fort Christina" as the level of the motor spirit in No. 8 starboard tank had risen, overflowed and finally the levels in the two tanks were equalised. The ullages of No. 8 starboard tank and No. 9 starboard tank at Avonmouth were 3 feet $2\frac{1}{2}$ inches and 7 feet $5\frac{1}{2}$ inches respectively. On the arrival of the tanker at Avonmouth the results of the examination of the samples of motor spirit taken from No. 8 starboard tank, and an average sample of motor spirit taken from tanks Nos. 1 to 7 inclusive showed that the contents of No. 8 starboard tank were seriously contaminated with gas oil. The details of this examination are contained in Appendix 2. This conclusion was confirmed by the examination carried out by the Shell Mex & B.P. Company.

Further, when the "Fort Christina" left Avonmouth the quantity of liquid in No. 8 starboard tank amounted to 7 tons. The tanker then proceeded to Hamble and Plymouth where she discharged 1,043 tons and 682 tons of gas oil respectively from No. 9 tank. When she arrived at Hamble the quantity of liquid in No. 8 starboard tank amounted to 70 tons. It is therefore quite clear that the motor spirit contained in No. 8 starboard tank of the "Fort Christina" was contaminated with gas oil. There must also have been some contamination of gas oil in No. 9 tank with motor spirit as the flash point of the gas oil at Bahrein was stated to have been 174° F. and this, on arrival at Avonmouth, was reduced to 166° F. in No. 9 port tank, 158° F. in No. 9 centre tank and 162° F. in No. 9 starboard tank. A bulk sample from the three compartments was also taken by Shell Mex & B.P. at Avonmouth, and the flash point was found to be 164° F.

The various possible ways in which contamination could have taken place were considered, such as leaking valves on pipe lines or a leaking bulkhead between tanks 8 and 9, or leaking valves between the two ship's pumps used

for pumping motor spirit and gas oil. After the tanker left this country in September, 1951, she was overhauled by the Sun Shipbuilding Company at Chester, Pennsylvania, U.S.A., during the following month and an examination was also carried out. The tanker returned to Avonmouth loaded with kerosene on the 12th November, 1951, when Mr. D. W. Gelling, Senior Engineer Surveyor, Ministry of Transport, went aboard and obtained details of the repairs carried out in America. A meeting was held in London with the representatives of the owners who supplied drawings showing the arrangements of the pipe lines in the vessel and the question of leakage was discussed with them in conjunction with Mr. A. H. Wilson, Senior Engineer Surveyor, Ministry of Transport. It was stated that the valves on the pipe line were tested in America and found to be tight; it was also stated that the valves between the pumps pumping motor spirit and gas oil were blanked off during pumping operations. The examination in America failed to disclose a leak in the bulkhead separating Nos. 8 and 9 starboard tanks.

It therefore appears probable that contamination of Nos. 8 and 9 starboard tanks must have taken place through a faulty weld in the bulkhead separating these two tanks. There was no other way in which contamination could occur at the depot at Avonmouth as separate pipe lines and connections were used for motor spirit and gas oil.

Further and conclusive evidence of contamination was furnished by the samples which were taken from the pipe line at the jetty whilst gas oil was being pumped from the tanker to No. 1 shore tank. The first sample taken had a flash point below 73° F. and a second sample had a flash point of 84° F. Subsequently a further sample was taken and this had a flash point of 150° F. It therefore seems fairly certain that the gas oil that was being pumped into No. 13 shore tank was contaminated with motor spirit.

It was subsequently found that the admixture of 2 per cent. by volume of motor spirit reduced the flash point of the gas oil to 84° F., whilst the addition of 3 per cent. by volume of motor spirit reduced the flash point to below 66° F.

(2) Some means of igniting the explosive atmosphere in shore tank No. 13

There are a number of possible sources of ignition which may have fired the explosive atmosphere in shore tank No. 13 and these are as follows:—

- (a) Smoking.
- (b) A spark produced by a locomotive in the siding close to the tank.
- (c) Lightning.
- (d) Micro-biological action.
- (e) Unexploded bomb dropped during the last war.
- (f) Electrical causes:—
 - (i) Stray earth currents.
 - (ii) Faulty current or leakage from the electrical installation.
 - (iii) Static electricity.

Taking these possibilities in order I think that (a), (b), (c), (e) and (f) (i) and (ii) may be eliminated for the following reasons:—

(a) Smoking

Both Baggs and Hyett were experienced and trusted men, and quite apart from this they were working in full view of the yard and the office, and it is extremely unlikely that they were smoking during the operation of pumping gas oil into shore tank No. 13.

(b) A spark produced by a locomotive in the siding close to the tank

At the time of the explosion there were no locomotives in operation at the Regent Company's oil installation. I was informed that the nearest locomotive was between the Cleveland Company's Depot and the Abadan Depot belonging to Shell Mex and B.P. This was at least 300 feet away. In view of the distance and the fact that the wind at the time would blow the spark away from the tank, this possibility can be ruled out.

(c) Lightning

The Meteorological Office have no record of any electrical disturbance in the Avonmouth area on the day of the accident. (See Appendix 3.) This possibility can therefore be dismissed.

(d) Micro-biological action

It is known that when tankers discharge different products they frequently clear their manifolds by pumping sea water through them to prevent contamination. Accordingly the Company had water bottoms in their gas oil storage tanks at Avonmouth. It was also stated that there was a good deal of corrosion of the tanks where the water bottom was situated. In view of this, and also of the fact that sewage might be discharged into the river Avon, it appeared that the water bottom of shore tank No. 13 might have contained sulphate-reducing bacteria, and these organisms may have produced some iron sulphide which might have ignited spontaneously when brought into contact with air. The contents of shore tank No. 13 were being disturbed by Hyett whilst dipping the tank.

It was not possible to obtain a sample from the water bottom of shore tank No. 13 after the accident, but samples were obtained from shore tanks Nos. 18 and 30. Both these shore tanks were used for the storage of gas oil and the water bottoms in these two tanks would be comparable with that in shore tank No. 13. These samples were submitted to the Chemical Research Laboratory, Teddington, for examination, and sulphate-reducing bacteria were found to be present in the water bottom obtained from shore tank No. 30. (See Appendix No. 4.) It is therefore possible that they may also have been present in the bottom of shore tank No. 13. It is possible that pyrophoric iron sulphide may have been present in shore tank No. 13 and glowing iron sulphide in this tank may have caused the ignition.

(e) Unexploded bomb dropped during the last war

An unexploded 500 kilogram bomb was recovered from No. 2 Depot of the Regent Oil Company Limited, on the 27th December, 1948, and it was thought that this accident may perhaps have been caused by the explosion of an unexploded bomb. In order to investigate this possibility it was arranged for the ground underneath tank No. 13 to be examined when it was dismantled. This examination was carried out by the Officers of the Bomb Disposal Unit and nothing was found to indicate the explosion of an unexploded bomb. This possibility can therefore be dismissed.

(f) Electrical causes

The 10 inch pipe line running from the jetty to the depot was, as previously stated, about 3,250 feet long. This pipe line was connected to shore tank No. 13, by means of a 6 inch pipe line about 50 feet long. This 6 inch pipe line delivered oil into this tank at roof level and not at the bottom of the tank, so that during pumping operations the oil would drop from the top of the tank.

If the tanker pumped at a constant rate of about 150 tons per hour it is estimated that the level of the oil in shore tank No. 13 would have risen a height of 5 feet from the time of starting pumping into this tank until the explosion occurred. On this assumption the linear velocity of the oil in the 10 inch diameter pipe line would be about 3.2 feet per second, and the linear velocity in the 6 inch diameter pipe line would be about 9 feet per second. It is highly probable that the rate of pumping was not constant and that it was considerably higher. In view of the possibility of the generation of a charge of static electricity either from the delivery pipe from the top of the tank or from the decrease in cross sectional area of the 10 inch pipe line to the 6 inch pipe line, it appeared quite probable that charges of static electricity were being built up in the oil. The relative humidity of the atmosphere at the time was 80 per cent. (See Appendix 3), and this would not preclude the build up of a static charge. Hyett was using a steel dip tape fitted with a heavy 4 inch brass weight which it was customary to lower to the bottom of the tank. The tape was enclosed in a leather case. It is therefore quite possible for the steel dip tape to take up a charge of static electricity from the oil in the tank, and to discharge by means of a spark against the edge of the 10 inch manhole in the top of the tank through which the dip tape was inserted. In order that this and other points should be investigated thoroughly, arrangements were made with Mr. Swann, H.M. Senior Electrical Inspector of Factories, for members of his staff to carry out an investigation at the depot. This has been done and the reports of Mr. Elliott, H.M. Electrical Inspector of Factories, and an extract from a memorandum by Mr. Leighton, H.M. Electrical Inspector of Factories, are contained in Appendix 5.

The result of this investigation shows that ignition from stray earth currents, or fault current or leakage from the electrical installation can be disregarded.

I discussed Mr. Elliott's report with him and Mr. Swann, and in view of the evidence furnished by three witnesses that Hyett had been dipping the tank with a steel dip tape, they agreed with me that the more probable cause of ignition was electrical sparking from the dip tape to the cover of the tank.

CONCLUSIONS

After taking all the facts into consideration, and in the absence of any evidence to the contrary, I am of the opinion that the explosion was caused by the presence of motor spirit in the gas oil pumped by the tanker "Fort Christina" into shore tank No. 13, and the motor spirit vapour present in shore tank No. 13 may have been ignited by a spark caused by the generation of a charge of static electricity in pumping the oil into that tank, or by the presence of glowing iron sulphide in the tank 13, and of these two possible causes the former is the more probable.

RECOMMENDATIONS

High flash point products

1. In view of the construction of certain war time tankers (T2 Type) whereby the products carried in them may become contaminated owing to leaking bulkheads, or faulty valves in the header attached to the pumps, it is desirable that the same precautions should be observed in dealing with petroleum products having a flash point of 73° F. and upwards as those for petroleum spirit (flash point below 73° F.).

Where the tankers are provided with separate pumps and pipe lines which are not inter-connected, and the products are separated in the tanker by double bulkheads, and also where separate product pipe lines are provided at the shore installations, this may not be necessary provided that there is no contamination with the previous cargo carried in the tanker. There is, however, always the danger of contamination owing to an accident of some kind.

This point should also be covered in the licensing of the premises concerned.

Water Supplies

2. It is quite clear that the water supplies available were insufficient as there was not enough water to cool all the tanks near the fire quite apart from supplying foam for extinguishing the fire. At one time an urgent request was sent out to cut down the cooling of tanks in order to provide water for fire fighting. Shell-Mex and B.P. had to stop cooling their tanks at the Abandan site so as to divert cooling water for the tanks at the Cleveland Company's Depot. In fact there was not sufficient water available until about 1½ hours after the fire occurred and the additional water was obtained by pumping water from the dock by the Fire Brigade. It is important that there should be adequate supplies of water regularly available both for cooling purposes and also for fire fighting.

I would therefore suggest that if practicable a ring main round the petroleum depots should be provided, and that this main should be so energised that an adequate supply of water is always available, and at a sufficient pressure to be used for efficient fire fighting with foam (about 150-160 lb. per square inch). Each tank should be provided with water nozzles for cooling purposes so that cooling can be applied at short notice.

Coal fired locomotives

3. Although there is no suggestion that this fire was caused by a spark from a locomotive in the vicinity of the depot, it is of importance that coal fired locomotives should not be allowed in the vicinity of the depots where petroleum spirit is kept. I was informed that a number of grass fires have occurred due to sparks or hot ashes, and it is important that this type of locomotive should be replaced by the diesel type.

Bunding of tank farm

4. The fire started at tank No. 13 and this was one of twelve tanks situated in a reinforced concrete bund. The fire spread to or damaged all the other tanks in the compound. There was a general conflagration in the bund and motor spirit was fed into the bund from a number of tanks. The heat to which the reinforced bund wall was exposed caused the wall to spall, and it was exceedingly fortunate that burning petroleum did not find its way on to the river Severn. This might have proved very serious as the bund was only a few feet from the river. I consider that this method of bunding is insufficient and that this should be suitably improved by providing some kind of heat insulation, as for instance, by the addition of earth bunding on the inside of the reinforced concrete wall, always provided that the wall is made sufficiently strong.

Bunding of tanks

5. There were in effect twelve separate tanks in one bund and I consider that this number of tanks is too large to have in one risk. It is true that in some cases at Avonmouth dwarf walls were erected between tanks, but these are useless unless they are imperforate. This was the case in the bund

adjoining the one in which the fire occurred. The holes in these dwarf walls, through which the pipe lines were carried were not sealed, and if leakage occurred from one tank the liquid could run through the dwarf wall.

I consider from a safety point of view that wherever practicable each tank of any size should be situated in its own imperforate bund so that in the event of a fire occurring the fire can be localised. The neighbouring tanks can then be cooled and if it is not possible to extinguish the fire easily it could, at the worst, burn itself out and not affect the remaining tanks. If separate bunds are provided it gives time to close the valves or do anything else that may be necessary to the adjacent tanks. The inter-bund walls should be nearly as high as the external bund wall. Each compound should be drained through an interceptor, and this should be controlled outside the bund. In this case, had Tank No. 2 been banded separately it is highly probable that the suction valve would have been closed as soon as the fire occurred.

Product pipe lines within the bund

6. The product pipe lines within the bund running beside the tanks Nos. 1, 2, 3 and 4 were all fractured as a result of the fire. If it is necessary or desirable for the pipe lines to be within the bund then I recommend that they should be enclosed in a brick or concrete chamber covered with concrete slabs to protect them from fire. Alternatively the pipe line should be placed outside the bund.

Spacing of tanks

7. The fire spread from tank No. 13 to tank No. 5 very rapidly, and this was probably due to the explosion in tank No. 13 fracturing the 6 inch connection to the top of this tank through which oil was being pumped and the delay in stopping oil being pumped from the ship through this pipe. Consequently a certain amount of burning oil may have been sprayed into the compound and on to tank No. 5. The other tanks were probably involved due to the presence of burning oil and spirit in the compound. In spite of this it appears to me to be desirable to increase the distance between the tanks in order to prevent the heating of the tanks by radiation in the event of a fire in one of them. It may be difficult to increase the separation in some cases, but wherever this is practicable the ideal distance is one diameter apart, or as near this figure as is practicable.

Filling pipe carried to the bottom of the tank

8. The filling pipe in tank No. 13 was not carried down to the bottom of the tank as was done in the case of those tanks used for the storage of petroleum spirit. This is quite understandable in the case of gas oil, as any electric discharge due to electrification of the oil would have no harmful effect owing to the high flash point of this product. In view, however, of the possibility of contamination with low flash products mentioned in recommendation No. 1 of this report, it would be a wise precaution to use bottom delivery and to incorporate a non-return valve with the delivery valve. This would prevent burning oil being projected into the bund in the event of an explosion in the tank.

Dipping from the top of tanks

9. Dipping tanks of gas oil from the roof of the tank would not normally constitute a hazard, but in view of this accident and particularly during pumping operations it would be a wise precaution to dispense with this method of determining the level of the liquid in the tank, and use instead a float or some other safe device to indicate the level of the liquid in the tank.

Local first-aid fire fighting

10. It is quite clear that the extent of a petroleum fire depends very much on what can be done in fighting the fire during the very early stages, namely, the first 5 or 10 minutes before the arrival of the Fire Brigade. It, therefore, seemed to me that it would be advisable to initiate a scheme whereby the licencees in Avonmouth Dock would organise amongst themselves a first-aid fire party to fight a fire which might occur in any of the premises of the Companies concerned. Accordingly, I approach the following firms with this end in view:—

Watsons Petroleum Co. Ltd., Cleveland Petroleum Co., Regent Oil Co. Ltd., Shell-Mex & B.P. Ltd., Esso Petroleum Co. Ltd., New Western Oil Storages Ltd., Wm. Butler & Co. (Bristol) Ltd.

These firms have agreed in principle to work out a scheme among themselves in order to train their personnel in fire fighting, have regular practices and pool their fire-fighting resources for first aid action. They point out however that during non-working time, i.e., week-ends, holidays and nights, the number of men available would be considerably reduced, and in the event of an accident they would probably be fully employed in taking preventive action, such as closing valves, etc., but they would do what they could. In these circumstances, therefore, I would recommend that during the non-working hours, if possible, some additional members of the fire brigade should be transferred to the Docks to deal with an outbreak of fire during these periods. It would also be necessary to introduce some means of rapid communication between the various depots so that in the event of a fire or explosion occurring no time would be lost in sending the necessary information as to the location, the number of men and equipment required. The telephone service is not considered to be satisfactory for this purpose.

Application of foam to storage tanks

11. The question of whether bottom injection of foam or top foam pourers should be used for the extinction of a fire in a tank containing petroleum spirit is a matter of opinion and has yet to be decided. In the case of some tanks at Avonmouth, some were fitted with bottom injection pipes, but some of these pipe connections were situated inside the bund so that, if they were to be used it would be necessary to go into the bund to connect up and open the suction valves if they were closed. Thus, if the fire was burning in the bund, some of the connections could not be made and the valves could not be opened.

Whichever system is used it is absolutely essential that the connections for the application of foam, by bottom injection or through dry risers to the top of the tank, should be external to the bund in an easily accessible position and several feet away from the bund to enable the mobile foam units to be connected up to the tank without being subjected to an undue amount of heat. If the bottom injection system is used then a suitable non-return valve should be fitted on the tankside of the suction valve, and the suction valve should be left open, otherwise it may not be possible to inject any foam into the tank.

If top pourers are installed, this should not necessarily be limited to one point but two or possibly three.

I recommend that the connections for the application of foam should be external to the bund in an easily accessible position away from the bund wall, and if bottom injection is used a suitable non-return valve should be fitted on the tankside of the suction valve and that the suction valve should be kept open.

OBSERVATIONS

(1) On the 29th May, 1940, a circular letter was sent from the Home Office to the Chief Officers of local fire brigades regarding fires at large oil depots. A copy of this letter is attached in Appendix 6.

This arrangement or a modification of it should be continued in the case of oil depots as it is obvious that the depot manager will know exactly what the conditions are in the various tanks, namely whether they are full or empty and what the risks are in his own depot. In view of this it is important that the depot manager and the chief officer of the fire brigade should consult together in fighting a fire in the depot.

(2) A copy of the licence issued by the local authority is contained in Appendix 7. The licences issued to the occupiers of the other depots in Avonmouth Dock have been examined and they are all in the same form. It appears to me that the local authority carry out their duties under the Petroleum (Consolidation) Act 1928 in a somewhat perfunctory manner.

In conclusion I would express my thanks to Mr. Swann, O.B.E., H.M. Senior Electrical Inspector of Factories, Mr. Elliott, H.M. Electrical Inspector of Factories, Major J. C. Hunt, M.B.E., Headquarters, Bomb Disposal Unit (U.K.), War Office, Mr. Butlin, Chemical Research Laboratory, Teddington, the Director of the Meteorological Office, Messrs. D. W. Gelling and A. H. Wilson, Senior Engineer Surveyors, Ministry of Transport, and Mr. Frost, Regent Oil Company, for the assistance they have rendered me in carrying out my Inquiry.

I have the honour to be, Sir,

Your obedient Servant,

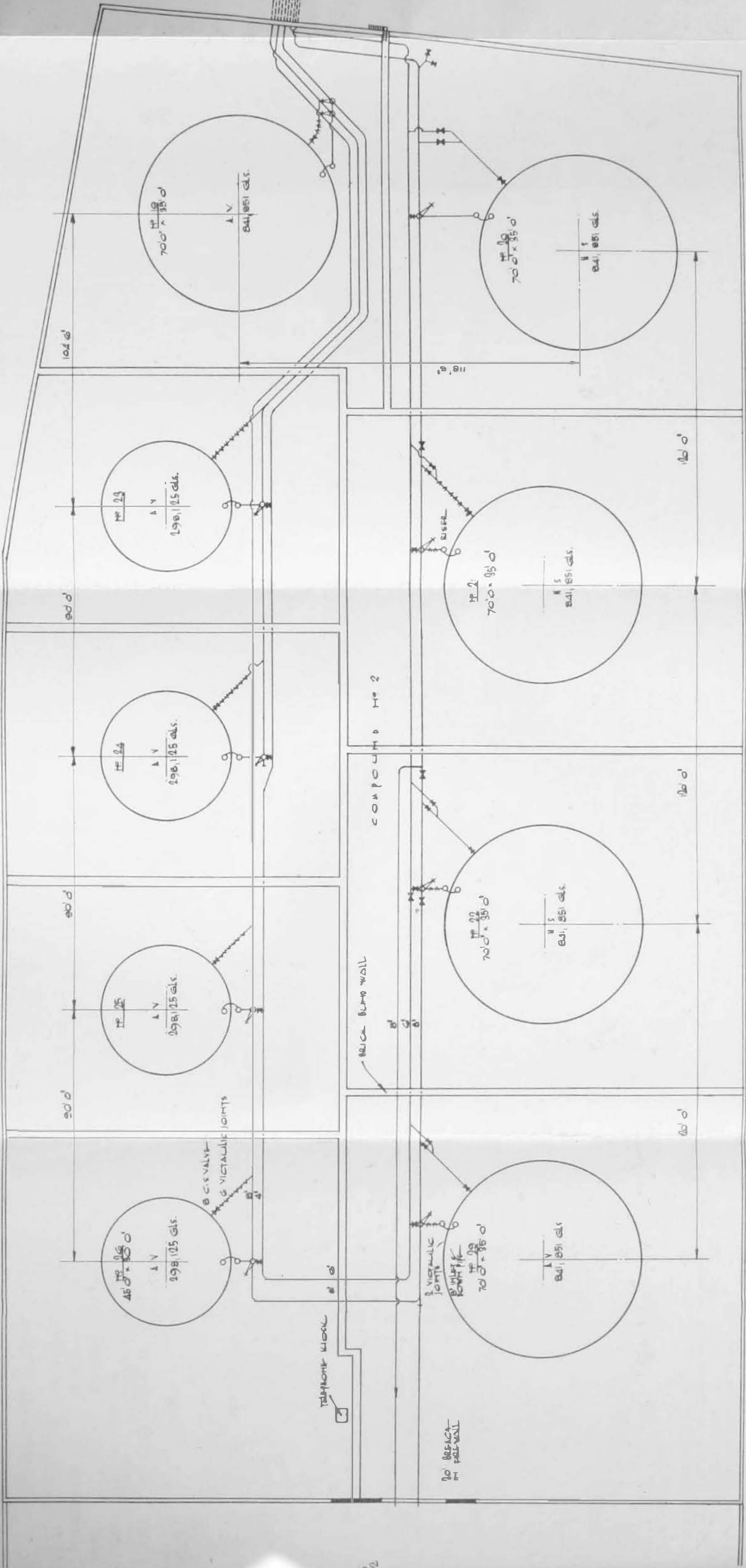
H. E. WATTS.

H.M. Chief Inspector of Explosives.

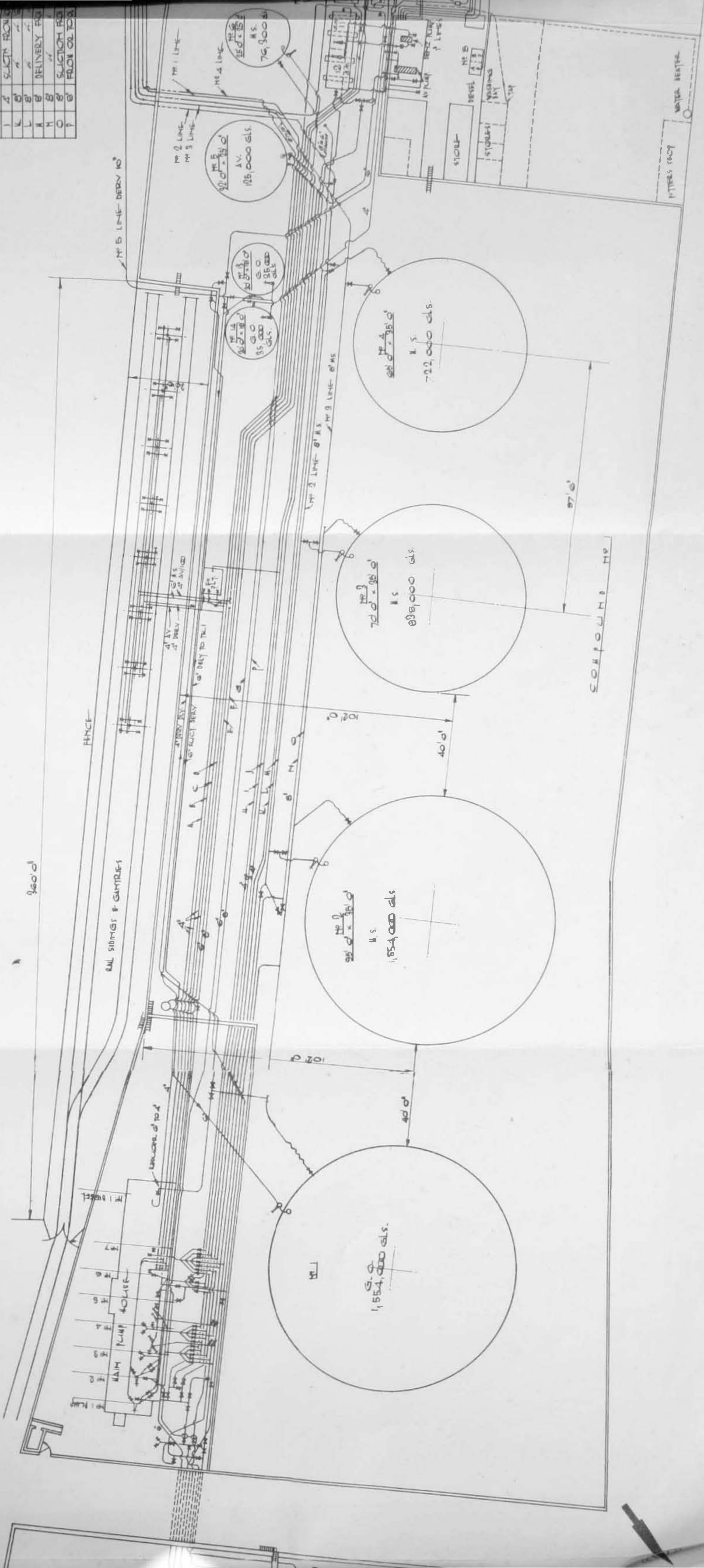
1

4

CH 100
11' 0"



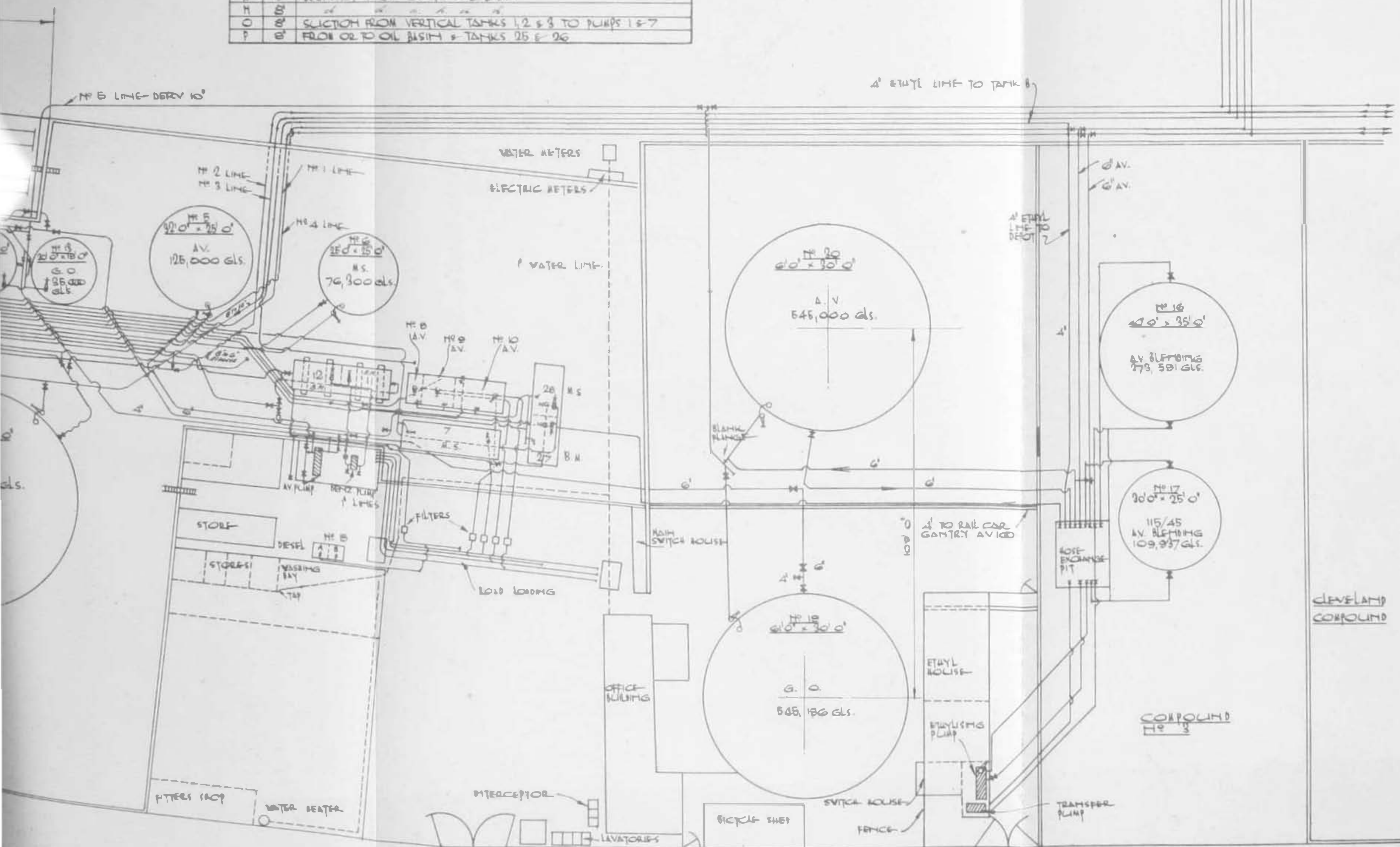
KEY TO		
MARK	SIZE	FROM PLANS
A	4"	1"
B	4"	2"
C	4"	3"
D	4"	4"
E	4"	5"
F	4"	6"
G	4"	7"
H	4"	8"
I	4"	9"
J	4"	10"
K	4"	11"
L	4"	12"
M	4"	13"
N	4"	14"
O	4"	15"
P	4"	16"



H^o 5 10^o DERV. LINE
 H^o 2 0^o N.S. LINE
 H^o 3 10^o N.S. LINE
 H^o 4 0^o SV LINE
 H^o 1 8^o SV LINE

(TO & FROM OIL BASIN)

Scale: One inch to forty feet



APPENDIX 2A
REGENT OIL COMPANY LTD.
LABORATORY REPORT

Laboratory: CENTRAL.

Date: 2nd October, 1951.

Report No.: C.L. 5158/B.Von/51.

Reference:

Sample No.: K. 8010.

Date Received: 17th September, 1951.

Nature of Sample: Motor Spirit contaminated ex Avonmouth Inst. Ship's tank No. 8 starboard. B/D "Fort Christina" D/D 5th September, 1951. Depot S/No. AVN./F/14. (1-gln).

Specific Gravity @ 60°F.	...	...	0.7347
Appearance	...	...	Clear
Colour	...	...	Orange
Odour	...	...
Reid Vapour Pressure (lbs.)	...	...	8.5
Existent Gum (mg/100 mls.)	...	...	1,700 approx.
Gum (mg/100 mls.) after extraction with I.P. spirit	...	...	1.6
Corrosive Sulphur (I.P. 65)	...	...
Corrosion (Cu Strip)	...	...	No change
Freezing Point (°C.)	...	...
Bromine Value	...	...	24
Aniline-Gravity Constant	...	...
Water Tolerance (mls.)	...	...
Lead Tetraethyl (ml./l.G.)	...	...	1.03
Aromatics (% vol.)	...	...
Total Sulphur (% wt.)	...	...	0.12

DISTILLATION (I.P.)

Barometer	...	763 mms.
Temperature	...	18°C.
I.B.P.	...	40
5% @	...	57
10% @	...	64
20% @	...	75.5
30% @	...	88
40% @	...	107
50% @	...	120.5
60% @	...	133.5
70% @	...	148
80% @	...	162
90% @	...	200
95% @	...	279.5
F.B.P.	...	288
Recovery	...	97.0%
Residue	...	1.5%
Loss	...	1.5%
% Evap. @ 70°C.	...	15.0%
% Evap. @ 125°C.	...	52.5%
% Evap. @ 180°C.	...	88.0%
% Evap. @	...	
% Evap. @	...	
% Evap. @	...	
% Evap. @	...	
Corr. Temp. °C.	...	19

Octane Number (Res. F.1.)	...	70.3	(Motor F.2.)	...	23.0 U.	...	65.7
(Rich Mixture F.4.)							

REMARKS:—The octane number (F.2.) is below specification. The existent gum of 1,700 mgms./100 mls. approximately is oily material. The % Evap. @ 180°C. is below specification. The F.B.P. is above specification. This sample is obviously contaminated with gas oil.

RS/CMR.
cc. Tech. Div.
Bulk S & S.
Avonmouth.

Prepared by: G. MAYHEW.

Signed by: R. SEFTON.

APPENDIX 2B
REGENT OIL COMPANY LTD.
LABORATORY REPORT

Laboratory: CENTRAL.

Date: 25th September, 1951.

Report No.: C.L. 5127/B. Von/51.

Reference:

Sample No.: K. 8012.

Date Received: 17th September, 1951.

Nature of Sample: (Normal) Motor Spirit ex Avonmouth Inst. Ship's average Tks. P.C.S. Nos. 1-7. "Fort Christina" Loading port Bahrein. D/D 5th September, 1951. Depot S/No. AVN/F/16. (1 Gall.).

Specific Gravity @ 60° F.	0.7234
Appearance	Clear
Colour	Orange
Odour	
Reid Vapour Pressure (lbs.)	8.8
Existent Gum (mg/100 mls.)	0.8
Gum, Potential, (mg/100 mls.)	
Gum, Lead Precipitate (mg/100 mls.)	
Corrosive Sulphur (I.P. 65)	
Corrosion (Cu Strip) @ 122° F.	No change
Freezing Point (°C.)	
Bromine Value	25
Aniline-Gravity Constant	
Water Tolerance (mls.)	
Lead Tetraethyl (ml./I.G.)	1.25
Aromatics (% vol.)	
Total Sulphur (% wt.)	0.06
Octane Number (Res. F.1.)	74.5
(Rich Mixture F.4.)	

DISTILLATION (I.P.)	
Barometer	756.6
Temperature	13.5°C.
I.B.P.	33.5
5% @	50.0
10% @	57.0
20% @	70.0
30% @	85.0
40% @	98.5
50% @	110.5
60% @	123.0
70% @	136.0
80% @	148.5
90% @	164.5
95% @	179.0
F.B.P.	192.0
Recovery	98.0%
Residue	1.2%
Loss	0.8%
% Evap. @ 70°C.	20.8%
% Evap. @ 125°C.	62.8%
% Evap. @ 180°C.	96.3%
% Evap. @	
% Evap. @	
% Evap. @	
Corr. Temp. °C.	15.5

28.0 U

REMARKS:—The Octane Number (F.2.) is slightly below specification.

RS/DMS.
c.c. Tech. Div.
Bulk S & S.
Avonmouth.

Prepared by: G. MAYHEW.
Signed by: R. SEFTON.

APPENDIX 3

METEOROLOGICAL OFFICE,
AIR MINISTRY,
DUNSTABLE.
BEDFORDSHIRE.

17th September, 1951.

In reply please quote :
M. 5518/51.

DEAR SIR.

In reply to your letter of 12th September, I forward herewith a copy of a report from the Meteorological Office at the Royal Air Force station, Filton, which is the nearest place to Avonmouth from which information is available.

As regards item (1) of your enquiry the practice at our observing stations is to read the dry and wet bulb thermometers a few minutes before each exact hour. The dry bulb gives the shade temperature and the humidity is computed from the readings of the two thermometers. On the occasion in question, the thermometers were read within a minute or two of 2.47 p.m. In addition the maximum temperature during the "day" period 06h.-18h. G.M.T. (7 a.m.-7 p.m. summer time) is read on a self-registering thermometer and the value for 6th September is given as item (4) of the report. No readings of "sun" temperatures are made at our stations.

Some further information is included in item (5) of the report, from which you will see that the sky was overcast at the time and the wind light northerly.

As regards electrical disturbances, we may amplify the "nil" report from Filton by stating that none of our stations reported thunder or lightning during the afternoon of 6th September, and none nearer than the English Channel were detected by our "Sferic" direction finders, the special function of which is to detect and locate thundery outbreaks.

Yours faithfully,
(Signed) E. L. BILHAM.

H.M. Chief Inspector of Explosives,
Room 420, Home Office, Whitehall, S.W.1.

Enclosure to Appendix 3

(Copy.)

METEOROLOGICAL OFFICE,
ROYAL AIR FORCE,
FILTON.
BRISTOL.

14th September, 1951.

Ref. FIL/7/31.

The Director,
Meteorological Office,
Dunstable, Beds.

Observations at Filton, 2.47 p.m. B.S.T. on 6th September, 1951

In accordance with the telephone request of Mr. Bilham, this morning, the following is the information required:—

1. Dry bulb temperature—69 degrees Fahr.
2. Relative Humidity—80 per cent.
3. Electrical disturbances—Nil.
4. Maximum day temperature during period 0600h-1800h G.M.T.—71 degrees Fahr.

- 5.—(a) Sunshine recorder reading—Nil.
(b) Total amount of cloud—8/8ths.
(c) Surface wind—North 6 miles per hour.

(Signed) J. V. JONES.

for Meteorological Officer i/c.

Copy to S. Met. Officer.
Gloucester, for information.

APPENDIX 4

SAMPLE FROM PETROL STORAGE TANKS (AVONMOUTH)

Description of samples

The samples (in Winchester quart bottles) were taken on 17th September, 1951, from tanks at Avonmouth North Installation (Regent Oil Company, Limited).

From Tank 30

- (1) 1st Draw-off. Yellow liquid with black deposit. The latter evolved copious H_2S when treated with dilute acid and consisted probably mostly of ferrous sulphide. The presence of ferrous sulphide suggests that sulphate-reducing bacteria had been active.
- (2) 2nd Draw-off. Yellow liquid with rusty deposit. No sulphide detected.

From Tank 18

- (1) 1st Draw-off. Mostly oil but with about 1 inch of water with rusty deposit. No sulphide.
- (2) 2nd Draw-off. Yellow liquid with darkish deposit. No sulphide.

Examination for presence of sulphate-reducing bacteria

1 ml. quantities of each sample were placed in 2 oz. bottles, which were then completely filled with a sulphate-lactate medium containing some ferrous salt. They were then stoppered, sealed and incubated at 30° C. The presence of viable non-halophilic* sulphate-reducing bacteria would have been shown by blackening of the medium, due to the formation of ferrous sulphide.

After one month's incubation no blackening had occurred and it can be assumed that none of the 1 ml. samples contained non-halophilic sulphate-reducers. It is possible that blackening might have occurred if larger quantities (> 1 ml.) had been incubated. The results show that very few, less than 1 cell/ml., were present.

These results were surprising, because the presence of a deposit of ferrous sulphide in the 1st Draw-off sample from Tank 30 strongly suggested that the organisms had been active in this tank. It was thought possible, however, that the organisms might be of the halophilic type, i.e., they might grow only in a medium containing 2-3 per cent. NaCl in addition to the other necessary nutrients (lactate, sulphate, etc.).

Accordingly 1 ml. of each sample was incubated anaerobically (similarly to the first series) with a sulphate-lactate medium containing 2-3 per cent. NaCl.

No blackening occurred after one month's incubation with the samples taken from Tank 18.

Blackening occurred after eight days in the two samples taken from Tank 30. Microscopical examination showed that an almost pure culture of sulphate-reducing bacteria had developed.

These results demonstrate the presence of halophilic strains of sulphate-reducing bacteria in the water in Tank 30. They explain the presence of ferrous sulphide in the 1st Draw-off sample and suggest that the source of sulphate-reducing bacteria was sea-water.

(Sgd.) K. R. BUTLIN.

Chemical Research Laboratory,
29th November, 1951.

* Halophilic (salt-loving) organisms are those which only grow in salt water, e.g., sea water, saline lakes.

APPENDIX 5

GROSVENOR GARDENS HOUSE,
GROSVENOR GARDENS,
S.W.1.

3rd October, 1951.

Dr. Watts.

Avonmouth Oil Fire

I send with this the top copy of Mr. Elliott's report of his investigation between 18th and 20th September. (Enclosure 1.).

A lot of data of a useful character is given and it seems to me that the question of an incendive static spark turns on two main conditions:—

(1) The filling pipe was not taken down to the bottom of the storage tank, and

(2) The tank in which the fire originated was not fabricated and welded, but the individual plates were secured by rivets or bolted construction.

The significance of point (1) lies in the fact that there would be a considerable gush of oil, dropping at first the full height of the tank and thus more likely to produce those features of turbulence and evaporation which are associated with the generation of static electricity.

Point (2) needs a little elaboration, because it leads to the possibility of a section of steelwork being isolated electrically by reason of the material used for making the joints or even by oxide film.

Mr. Elliott made some tests for electrostatic charges using an instrument which has just been put on the market as a result of work done in the research laboratories of the Dunlop Rubber Co., Birmingham. This instrument is capable of quantitative measurement and he found that a similar gas oil to that being pumped into the tank which exploded was capable of electrification even in small quantities.

There seems, therefore, to be some reasonable ground for assuming internal electrification in this tank at a time when there may have been sufficient petrol contamination to form an explosive mixture in the air space above the level to which the tank had been filled.

Mr. Elliott is inclined to visualise incendive sparking between areas of different potential in much the same way as a flash of lightning takes place between clouds. There is literature which supports this view, e.g. U.S. Bureau of Mines. Bulletin 368, 1939. It is also possible that there could be moisture included in the gas oil which might have some effect in the accumulation of the static charges.

The possibility of a steel plate being electrically isolated in the neighbourhood of electrified areas might lead to sparking over joints above oil level, and thus point (2) may be of some importance.

You will see that the conditions for an incendive spark are not the same as those which existed in the Glyco Petroleum case. In this latter instance the supply, or filling, pipe was not in contact with the metalwork of the tank, but at Avonmouth it was welded to the top structure. Again at Glyco this rising main to the filler aperture was electrically discontinuous by reason of insulating material used at the flange joints between the centrifugal pump and the discharge. I took the view, as you will remember at that time, that this could lead to the piling up of voltage between each successive flange and finally between the pipe and the structure of the tank. The final spark would then be expected at the place where the down pipe entered the manhole, which also happened to be the point at which the mixture with air would be the most likely to explode. If incendive sparking were possible at Avonmouth it might be between an isolated section of the plating of the tank or between the different areas of the static in the oil. I am not sure how far this latter theory can be taken but Mr. Gilchrist, with whom Mr. Elliott had an interesting discussion, is a London

Officer of the Regent Co., and it might be possible to rig up a small scale edition of the Avonmouth tank at their Battersea Depot and take some further readings with the new instrument under conditions of insulation and earthing which Mr. Elliott would be prepared to specify.

After you have read his report and this covering note, you might like to have a talk about this or any other point which seems to arise on the report.

(Sgd.) H. W. SWANN.

Note: Meeting with Mr. Swann and Mr. Elliott on 29th October, 1951

I pointed out that evidence regarding the dipper was not complete as three witnesses had seen Hyett dipping shore tank No. 13. In view of this additional evidence both Mr. Swann and Mr. Elliott agreed that the more probable cause of ignition was sparking from the dipping tape to the cover of the tank.

(Sgd.) H. E. WATTS.

APPENDIX 5 Enclosure 1

FIRE AT OIL STORAGE DEPOT OF REGENT OIL CO. LTD., AVONMOUTH DOCK

Investigation made on 18th, 19th and 20th September, 1951

Interviewed:

Mr. Illingworth, Asst. Depot Superintendent, Regent Oil Co., Ltd.
Mr. Gilchrist, Senior Electrical Engineer, Regent Oil Co., Ltd.
Mr. Roberts, Asst. Electrical Engineer, Regent Oil Co., Ltd.
Mr. Legg, Engineer, Regent Oil Co., Ltd.
Mr. Phillips, Substation Engineer, Port of Bristol Authority.
Maintenance Electrician, Port of Bristol Authority.

General

The fire occurred in the walled compound which was the original storage installation and which has since been extended by the addition of other compounds, one at each end and one on one side (see Fig. 1). The fire in this compound destroyed or damaged almost everything within it, but by virtue of the wall, good work on the part of the Fire Brigade and good fortune with the winds, was prevented from extending to the remainder of the installation.

Tanks Nos. 13 and 14 amongst others are used for gas oil and No. 13 was being filled when the explosion and subsequent fire occurred. This fire then extended to the remainder of the tanks within the compound. Tanks 13 and 14 are each approximately 20 ft. diameter and 17 ft. 6 in. high and hold when full roughly 120 tons of gas oil. Tank No. 13 was being filled with oil from a tanker through a 10 in. delivery line some 3,000 ft. long from the ship. At 2.30 p.m. on the day of the fire Tank No. 13 was at about 5 ft. level. At about 2.47 p.m. the tank was very roughly at about 15 ft. level and two men, a dipper and a sampler, were sent to take the level and sample the oil. The dipper was on the top of the tank and the sampler was on the ladder on his way up when the explosion occurred. Both men were killed.

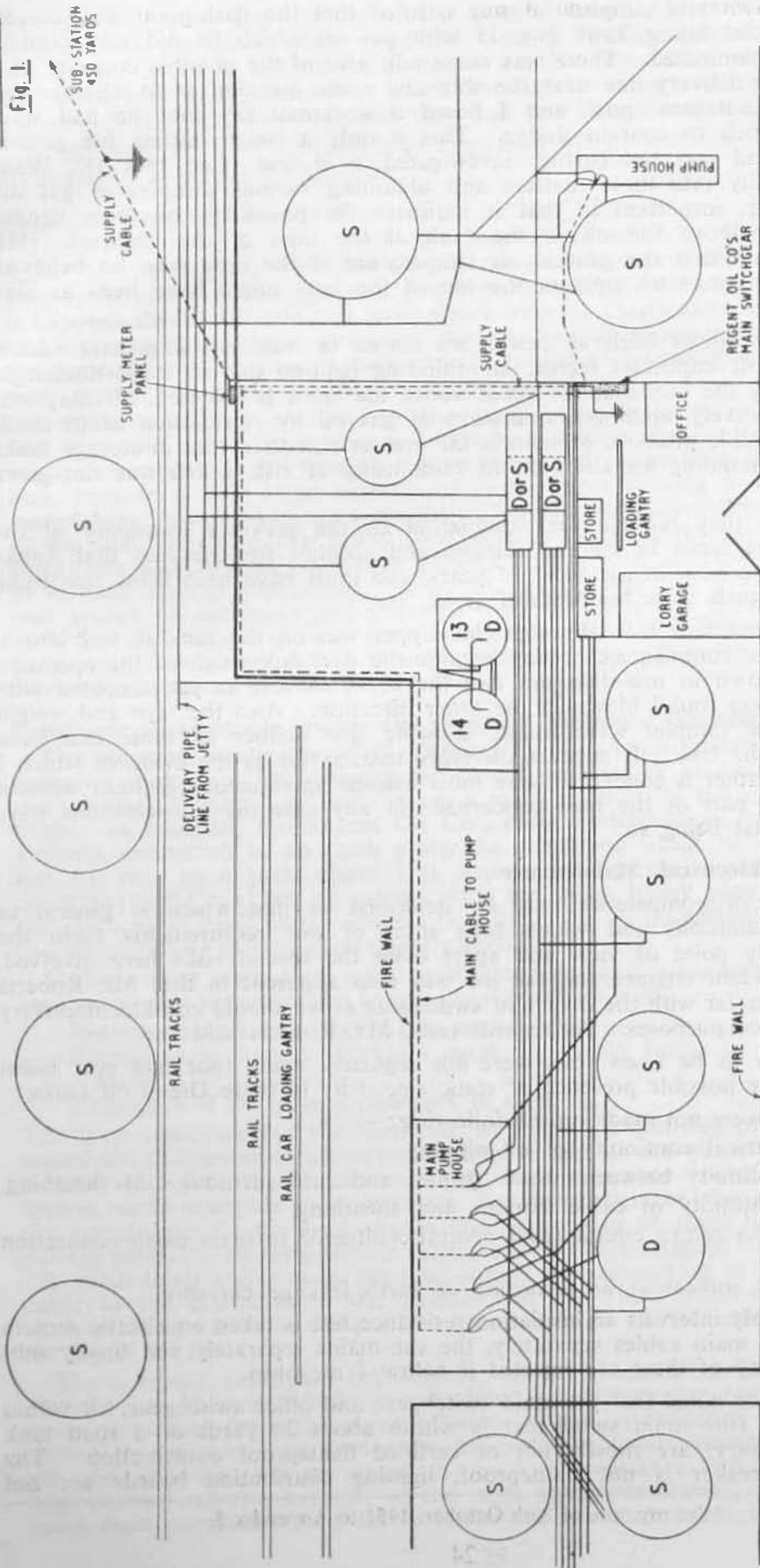
The rate of pumping is high, the turbulence and aeration are great, and as the delivery pipe into the top of the tank projects only about 6 in. to 1 ft. below the tank roof there would be a heavy stream of oil at first falling some 12 ft. and as the tank reached the 15 ft. level, falling some 2 ft. 6 in. to 3 ft.

Besides the delivery pipe into the top of the tank there is a 10 in. manhole, which was open, a vent pipe of about 6 in. diameter and a dipping orifice of about the same diameter.

On the ship, the gas oil was carried in a tank adjacent to a tank containing spirit and the ship's Captain had reported some contamination of the gas oil by spirit. Mr. Illingworth said that a first flow had been run into another tank and sampled by them and found contaminated. After a certain amount

APPENDIX 5.

Fig. 1.



Tank No. 13 was seat of fire.

D = Diesel or Gas Oil.
S = Motor Spirit.

Cable runs shown dotted
Diagrammatic - Not to Scale.

R E E R S E V E A R N

had been drawn and sampled he was satisfied that the flash-point was correct and commenced filling Tank No. 13 with gas oil which he did not consider was then contaminated. There was some talk also of the possible contents of a branch in the delivery line near the ship and some question as to whether this might have contained spirit, and I heard a workman say that he had since seen this branch to contain sludge. This is only a rough outline for general description and was not further investigated as it was plain that Dr. Watts was going fully into these matters and obtaining various samples of gas oil. It is, however, important in that it indicates the possibility of spirit vapour in the space above the oil in the tank at the time of the accident. Mr. Illingworth said that the general air temperature at the time was, he believed, about 60° F. but in his opinion the top of the tank might have been as high as 80° F.

Where light spirits such as petrol are stored in bulk, an important factor, if not the most important factor, in inhibiting ignition due to static discharges is undoubtedly the fact that the space above the spirit is too rich. It may well be that a relatively small contamination of gas oil by spirit, such as to result in an inflammable mixture, presents a far greater risk than that in storage tanks for spirit, demanding an attention to minimising of risk which was not given in this case.

This aspect may provide the explanation of the previous immunity of the gas oil storage tanks in the installation, and account for the fact that Tanks 13 and 14 have been in use some 15 years, and must have been filled, according to Mr. Illingworth, some hundreds of times.

* Mr. Roberts said that although the dipper was on the tank it was known that he had not commenced dipping because the steel tape used for the operation was found blown in one direction and the brass weight, as yet uncoated with water paste, was found blown in the other direction. Also the tape and weight carried by the sampler were found, showing that neither of these had been inserted into the tank. It appears therefore that, as far as the evidence which I was able to gather is concerned, one must assume spontaneous ignition without action on the part of the men concerned—in any case my investigations were based upon that being so.

Standard of Electrical Maintenance

The degree of competence may be described as that which is general in industrial installations and which falls short of our requirements from the electrical safety point of view and apart from the special risks here involved. Lack of a resident engineer on the job was also apparent in that Mr. Roberts was not so familiar with the details of switchgear as we should consider necessary for maintenance purposes. As regards tests, Mr. Roberts said:—

(a) As far as he knew tests were not regularly made (nor had ever been) regarding the possible presence of static electricity in these Diesel oil tanks.

(b) Tests were not made on the following:—

- (i) Electrical continuity of oil piping.
- (ii) Continuity between motor frames and cable armour and sheathing.
- (iii) Continuity of cable armour and sheathing.
- (iv) Earth return circuit from neutral conductor to main earth connection (loop test).
- (v) Test, indication or recording of earth leakage currents.

At six-monthly intervals an insulation resistance test is taken on electric motors separately, the main cables separately, the sub-mains separately and finally sub-circuits, and any of these are rejected if below 1 megohm.

It may also be noted that the main switchgear and office switchgear, all within a danger area (the main switchgear is within about 20 yards of a road tank car-loading gantry) are mostly not of certified flameproof construction. The main circuit-breaker is not flameproof, lighting distribution boards are not

* See my note of 29th October, 1951 to Appendix 5.

certified flameproof and these are in a brick shed with galvanised iron doors, opening into the space where road car loading is done. In the office itself, the lighting switches are of "gas tight" construction. The reason for this, Mr. Roberts said, was that they were installed at about 1930 before certified flameproof gear was available and they had not been changed since.

In addition the level of knowledge regarding the precautions to be taken on static risks was not of a high order.

Electrical Continuity of Oil Pipework

These two tanks sit on a hard core base above which is placed a layer of sand. Mr. Roberts said he had on one occasion measured the resistance of a tank to earth before its pipework had been connected and had found 0.2 ohm. It happens that I obtained this same figure between the remains of Tank No. 13 and the pipework system generally, though, having regard to the flooding of the compound by the Fire Brigade and the masses of pipework wreckage present when my test was made, the figure is of little value.

I made a number of tests on the general continuity of the pipe system and it should be understood that this system within the compound was very much more dense at the time of the accident than at the time of my investigation, because a very large number of heavy pipes flowing through the compound have been broken up, distorted and made fully discontinuous as a result of the fire. Even so, the heavy pipework is so extensive that in my view it constitutes a solid earth electrode capable of carrying all fault currents likely to be met on this installation. It is not intentionally connected to the water pipe system of the docks and although it no doubt in fact forms a solid earth with the water pipe system, good practice would have dictated that such a permanent connection should also have been made. Results of tests in this connection are given in Enclosure 1A.

Continuity of Electrical System and Overload Protective Apparatus

The electrical continuity of the Regent Oil Co. main switchgear and heavy pumping motors is by lead-covered cables and via a lead-covered cable to the sub-station neutral, so that there is a metallic return to the supply via buried cable. In addition, the Regent Oil Co.'s main switchgear is, according to Mr. Roberts, connected to an earth plate, the details of which he does not know, but this may be a plate about 3 ft. square. All pump motors are, however, connected solid via the oil pumps with the main heavy pipe system. Thus the earth plate itself at the Regent Oil Co. plays an insignificant part, and the overall continuity is quite exceptionally good.

Multiple loop tests were made at Regent Oil Co.'s main switchgear and the resistances were separated out to give the following results:—

Resistance of supply neutral to earth	... ..	0.2 ohm
Resistance of Regent Oil Co.'s main switchgear frame to earth	... ..	0 ohm
Resistance of the general pipework to earth	... ..	0.07 ohm

The loop resistance for the clearance of faults on the Regent Oil Co.'s main motor circuit-breaker is accordingly 0.2 ohm and as the phase to earth voltage is 210 volts A.C. the maximum earth fault clearance is 1050A. The sub-station earth electrode is formed by the connection of the neutral point of the transformer to the lead sheath and armouring of three outgoing medium voltage cables (all of considerable length, the cable to the Regent Oil Co. being about 450 yards long) and also to the lead sheath and armouring of the high tension cable to the substation. Mr. Phillips did not know whether there was an earth plate in addition. There had been no faults in any part of the area on the day of the fire.

The overload setting of the Regent Oil Co.'s circuit-breaker is 900A (time element not known), which is just about satisfactory for fault clearance, but more important from the point of view of the investigation of this fire, the setting of the substation feeder circuit-breaker is lower, being 440A to trip in 10 secs. and this, having regard to the loop resistance and the exceptionally high current carrying capacity of the earth continuity system, disposes of heavy earth fault occurrence as a factor in the causation of the accident.

Neither Mr. Phillips nor Mr. Roberts were suitably aware of these details and figures would have to be obtained from the manufacturers in order to provide exact data, though this is hardly necessary from the point of view of this inquiry. Likewise, as regards rupturing capacity, this is not known for either switch but the transformer bank is only 300kVA at 3.2 per cent. impedance, so that with a potential fault energy of 10 mVA the conditions are not onerous. It should be checked for the future, but has no bearing on the fire as it was definitely stated that neither the Regent Oil Co.'s breaker nor the substation breaker opened at the time until tripped by hand.

Stray Earth Currents

Tests were made by measuring voltages and currents between various pipes, cables, neutral connections, etc. In every case there was complete zero on A.C. with the exception of between the neutral conductor of the system and pipework. This gave 0.37V and 0.5V A.C. in two tests, is a very good figure and does not involve currents of any degree of danger. On D.C., minute potentials and currents could be measured, the latter being of the order of a few milliamps. These are doubtless either electrolytic in origin or from a known remote D.C. plant in the docks and have no significance.

ASSESSMENT OF POSSIBLE CAUSES OF THE FIRE

1. Non-Electrical

The Engineers of the Regent Oil Co. had apparently considered whether the tank could have burst as a result of too rapid pumping, the tearing of a metallic filament of a plate at the moment of fracture resulting in its being heated and igniting a vapour/air mixture. There were, however, the 10" manhole open, the normal vent open and the dipper orifice open, and this view they have accordingly discarded.

Further attention was not given to this, as it has no doubt been considered by Dr. Watts and is non-electrical.

2. Electrical Fault Current or Leakage

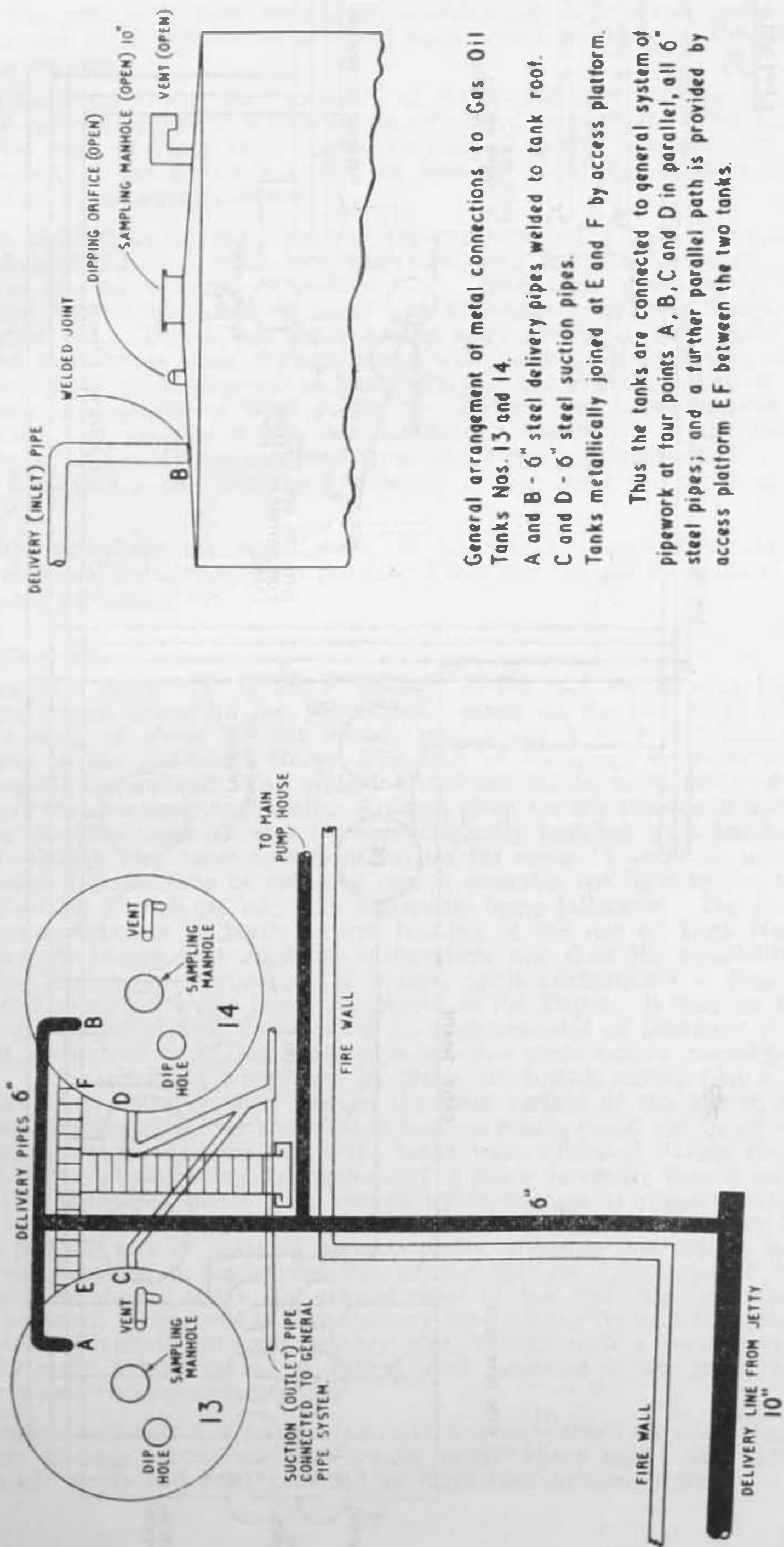
Two possible variations may be considered:—

(a) The lead-covered cable from the Regent Oil Co.'s main switchgear to their main pump house passes along the inside of the wall and within a few feet of Tank 13, this cable being about 2' 6" below ground. Had a dead fault occurred on this cable, the question arises whether current in sufficient quantity could have flowed to the tank or its pipework on its path back to the general mass of earth and caused sufficient local heating to give a hot metallic spot in the roof of the tank. The general arrangement of the pipework is shown in Fig. 2. From this sketch it is seen that Tanks 13 and 14 would be electrically in parallel to such a path with four ways of entry or exit, viz., suction pipe to Tank 13, suction pipe of Tank 14, inlet pipe of Tank 13 and inlet pipe of Tank 14. The 6" inlet pipes are welded to the tank roofs and it is considered that the current flow via these parallel paths such as might cause local heating of metal, would be a current greatly in excess of that at which either circuit-breaker would clear. Moreover, in the event of a cable fault, there would be a path from the cable sheath to an exceptionally good earth on the supply side and an exceptionally good earth on the motor side where the main pipework system is also very extensive; this is shown diagrammatically in Fig. 3 and it is not possible to visualise a heavy current flow from the cable sheath into the tank.

(b) A fault current of smaller magnitude than visualised in (a) above, but persisting for a considerable period, when flowing from a buried cable sheath into surrounding soil may sometimes dissipate such heat as to raise the temperature to the point where water is driven off in vapour form. It has been considered whether, flowing between the cable sheath and No. 13 or No. 14 tank or its pipework, such a current might so overheat the oil-laden ground within the compound as to cause an oil fire at the ground surface. The flame if rising to tank height could then possibly ignite vapour emerging

APPENDIX 5.

Fig. 2.



General arrangement of metal connections to Gas Oil Tanks Nos. 13 and 14.

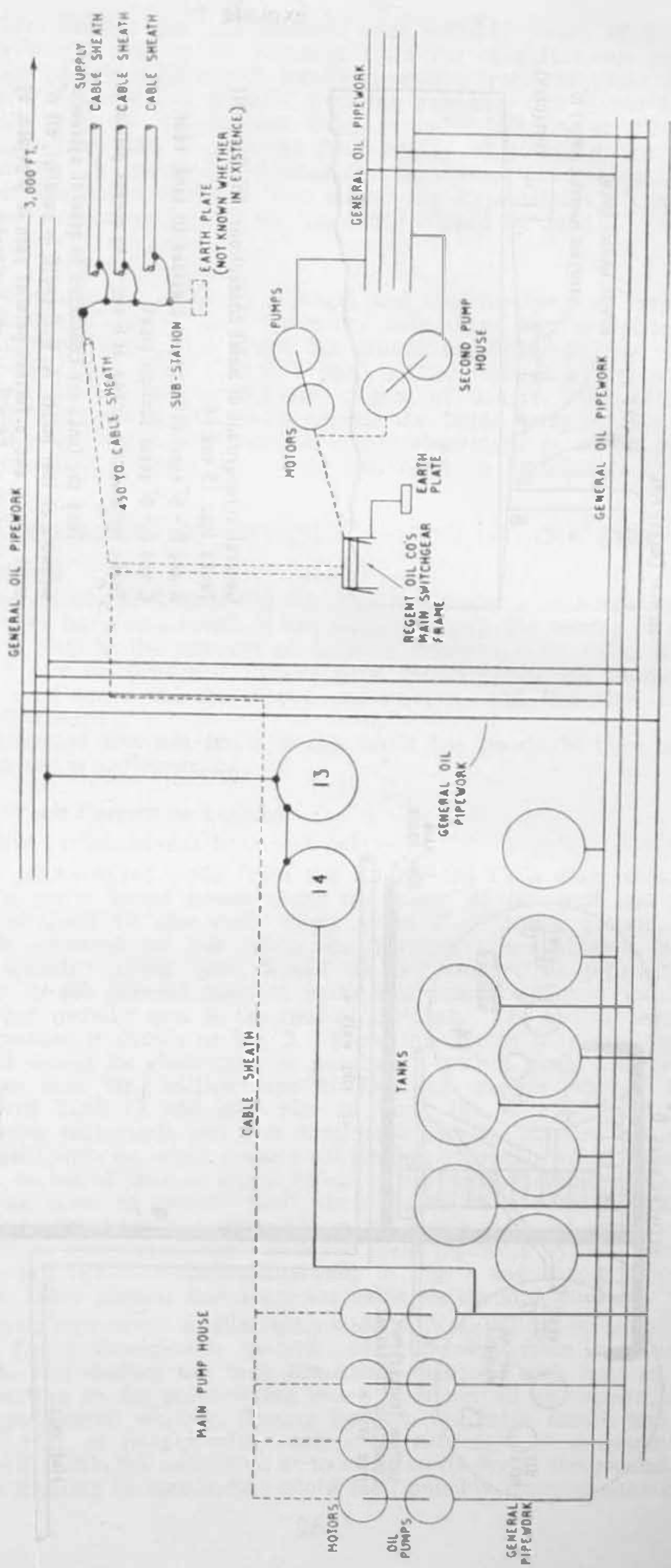
A and B - 6" steel delivery pipes welded to tank roof.

C and D - 6" steel suction pipes.

Tanks metallically joined at E and F by access platform.

Thus the tanks are connected to general system of pipework at four points A, B, C and D in parallel, all 6" steel pipes; and a further parallel path is provided by access platform EF between the two tanks.

APPENDIX 5.
Fig. 3.



General Schematic Arrangement of Earthing System, showing how Regent Oil Co's earthing conductors (cable sheaths—dotted) are tied at substation with other feeder cable sheaths and via their own motors and pumps with the general pipework of the depot. The result is an extremely "solid" earth network.

from the top openings, blow back and explode the tank. There are two reasons for disposing of this possibility:—

(i) The process is slow with much evolution of vapour and could not have taken place without some visual signs which would have been seen by the two men.

(ii) As in (a) above, the "solidity" of the general pipe network is such that a sufficient potential would not be developed between the cable sheath and the tank or pipes as to allow the flow of current necessary for the dissipation of the kilowatts needed to heat up a volume of some cubic feet of earth and start an oil fire.

The two possibilities (a) and (b) above, presuppose a heavy fault in the cable between Regent Oil Co.'s main switchgear and their main pump house; and there is, so far, no evidence of such a fault. The cable measured by Mr. Roberts and Mr. Phillips after the event (see Enclosure 1 (B)) was found low on insulation test. This is ascribable to the entry of fire brigade water via two buried joint boxes when the compound was flooded. A fault in a cable which blows itself clear, although a freak effect, is not entirely unknown and for certainty in disposing of these points, Mr. Roberts was asked to strip the faulty section and examine it with Mr. Leighton. The results of the cutting and testing of this cable are extracted from Mr. Leighton's Memorandum and given in Enclosure 1 (B), and the conclusion is that there was no fault on the cable.

This then completes the investigation as regards fault current or leakage from the electrical installation. It is considered that this was not the cause of the explosion and subsequent fire.

3. Static Electricity

The lack of a down tube in the 6" delivery to the tank results in a heavy, fast-moving stream (about 18 feet per second) issuing via the tank roof, falling through a drop of about 13 feet initially and about 2 to 3 feet finally at the moment of the accident. Heavy formation of oil spray, volatilisation of any light-spirit contaminant, and violent turbulence in the main body of the contents are the accompanying results. Reasons given for the absence of a down tube were that the tanks 13 and 14 were originally installed as a temporary expedient—though they have now been in use for some 15 years or so—and that although a down tube or swinging arm is desirable for light spirits, there was no need for it with gas oil; both arguments being fallacious. The formation of spark discharge in tanks a mere fraction of the size of Tank No. 13 is well enough known and needs no elaboration, nor does the possibility of ignition by this means, particularly if a light spirit contaminant is found to have existed even within the limits acceptable to the Depot. It may be mentioned that the roof plate construction of the tank consisted of treatment of the peripheral surface of each tank plate with asbestos paste before assembly for tightness. The tank being temporary the plates are bolted, having first a lead washer and then a steel washer between the plate surface of the nut on each side. Tests between plates were not made because results could not be of value having regard to the heat to which the tanks were subjected during the fire and might give a misleading impression. I suggest, however, that it cannot be said that individual plates were necessarily in contact as regards static at the time of the accident and if any joints were of high resistance, this may have played a part by way of sparking between plates, although this process is not in any way essential to an explanation of the ignition by reason of static electricity. As shown above the general mass of the tank was undoubtedly at earth potential. There was in each delivery pipe a Vitraulic joint for inducing the necessary flexibility into the delivery pipe, though such a joint does not necessarily mean a high value. A typical joint measured in the pump house in fact gave zero resistance reading.

Mr. Roberts said that it is his practice (and it is undoubtedly a good practice) to provide a copper bond across Vitraulic joints where light spirit is used, but no such bonds had been provided in these two delivery pipes.

As a small-scale "model" experiment, a number of tests were done on a flow of gas oil from a 1" nozzle (of the ordinary petrol pump type), the gas oil falling some 5 ft. into an open metal oil drum. The gas oil used was said not to have been taken from the particular ship concerned, but was simply a representative type of the gas oil stored in the Depot. It is not intended to suggest that these tests are in any way representative of what would or might occur within Tank No. 13, but they do show that this commercial grade of gas oil was capable of producing static electrical charges with a very small quantity of the gas oil (5 to 40 gallons) flowing through a very small jet for a very small time. In the tests, potentials of several hundreds of volts were obtained. It will be seen that the quantities of oil are small, and it is to be expected that the potentials within the tank would be very high. There is no doubt that the charges within the tank would be adequate to cause sparking. Submersion of the inlet pipe may be expected to reduce the risk but certainly not to remove it altogether and, whether commercially practicable, or not, in oil storage depots the risk cannot be entirely removed unless the gas above the liquid level is rendered non-inflammable, e.g., by purging with CO₂ before filling, or by adopting on a larger scale the introduction of solid CO₂ as is already an established practice in small tanks such as aircraft tanks.

APPENDIX 5. Enclosure 1(A)

The resistance across a number of joints in 6" pipes was taken. These were of the order of 0.0004 to 0.0006 ohm. The joint surfaces are packed for oil tightness but the continuity is made by the flange bolts which may be about six $\frac{1}{2}$ " bolts on some joints and thirteen $\frac{1}{2}$ " bolts on other joints. The current carrying capacity is therefore high and it will be appreciated that the network of pipes is so dense that frequently a current route would have a number of paths in parallel.

A length of 6" pipe 2' 6" long gave a figure of 0.0005 ohm. This again is a random value with possibly many actual parallel paths between the two points of contact of the instrument.

The resistance to earth of the main delivery pipe from the ship to Tank No. 13 was measured via two separate routes. One gave 0.07 ohm and the other 0.09 ohm. From the point of view of discharge of static, the delivery pipe can therefore be taken as an earth of negligible resistance.

APPENDIX 5. Enclosure 1(B)

Extract from Mr. Leightou's Memorandum on Cable from Regent Oil Co.'s main switchgear to their main Pump House

"A sketch (Fig. 4) shows the layout. The piece of cable between the two joint boxes was inserted to replace a damaged portion of the original cable about six years ago.

The inspection and tests proved, in my opinion, that no fault occurred in this cable. The insulation values at joint box B were low, and some water was found in the lead wrapping and paper insulation at the end of the box near the pumphouse. The compound and all other installation were, however, in excellent condition, and no signs of burning, puncture or flashover were seen.

The details of the tests were as follows:—

(1) Megger test of cable between first cut and switchgear near Regent Co. office—

Between any core and sheath—20 megohms.

Between any pair of cores—20 megohms.

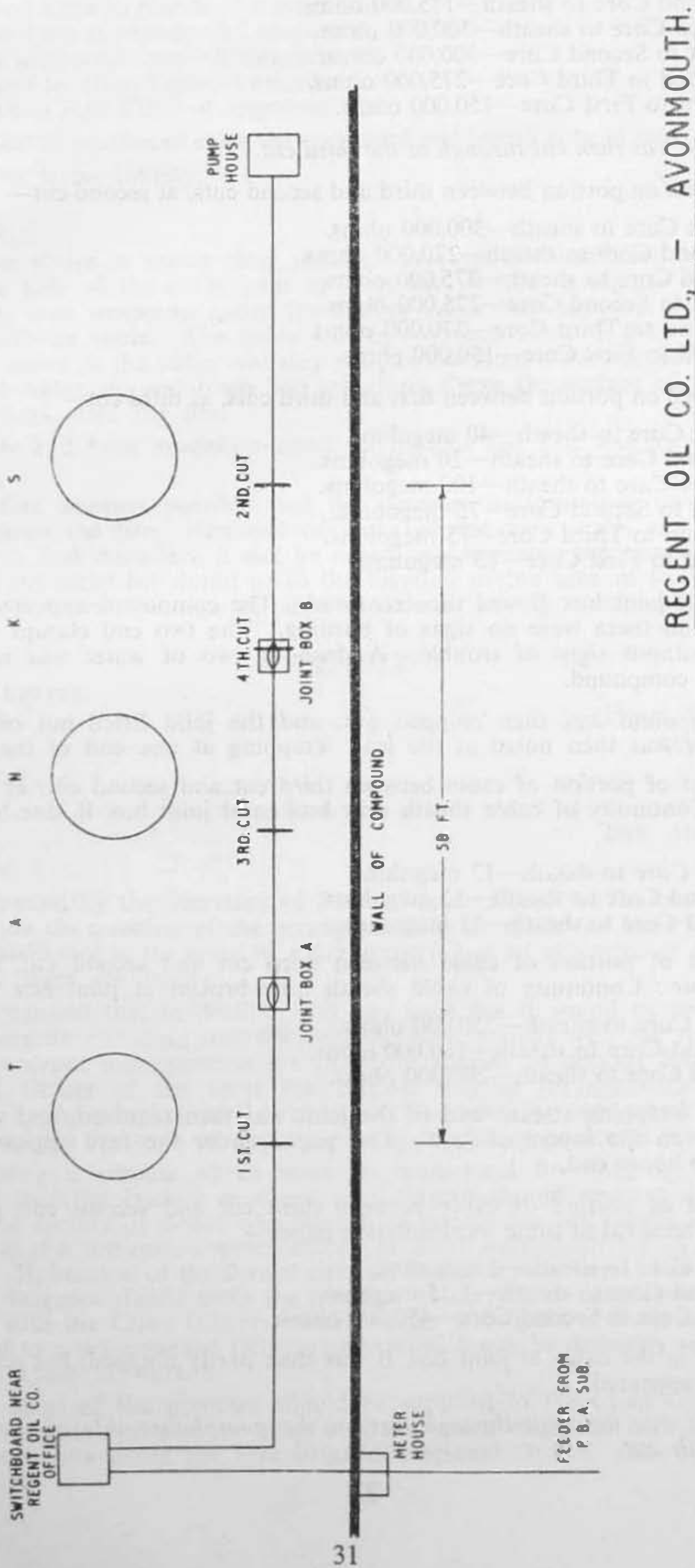
(2) Megger test of cable between second cut and Pumphouse—

Between any core and sheath—Infinity.

Between any pair of cores—Infinity.

APPENDIX 5.

Fig. 4.



(3) Tests on portion of cable removed between first and second cuts, at second cut—

First Core to sheath—200,000 ohms.
Second Core to sheath—175,000 ohms.
Third Core to sheath—300,000 ohms.
First to Second Core—300,000 ohms.
Second to Third Core—275,000 ohms.
Third to First Core—150,000 ohms.

The cable was then cut through at the third cut.

(4) Tests on portion between third and second cuts, at second cut—

First Core to sheath—300,000 ohms.
Second Core to sheath—220,000 ohms.
Third Core to sheath—375,000 ohms.
First to Second Core—275,000 ohms.
Second to Third Core—270,000 ohms.
Third to First Core—150,000 ohms.

(5) Tests on portion between first and third cuts, at third cut—

First Core to sheath—40 megohms.
Second Core to sheath—20 megohms.
Third Core to sheath—100 megohms.
First to Second Core—75 megohms.
Second to Third Core—75 megohms.
Third to First Core—15 megohms.

The lid of joint box B was then removed. The compound appeared in good condition and there were no signs of burning. The two end clamps were then removed without signs of trouble. A drop or two of water was noted in a hole in the compound.

The compound was then chipped out, and the joint lifted out of the box. Some water was then noted at the lead wrapping at one end of the box.

(6) Test of portion of cable between third cut and second cut, at third cut. (*Note: Continuity of cable sheath now broken at joint box B, due to removal of box.*)

First Core to sheath—12 megohms.
Second Core to sheath—12 megohms.
Third Core to sheath—11 megohms.

(7) Test of portion of cable between third cut and second cut, at second cut. (*Note: Continuity of cable sheath now broken at joint box B.*)

First Core to sheath—250,000 ohms.
Second Core to sheath—160,000 ohms.
Third Core to sheath—200,000 ohms.

The lead wrapping at each end of the joint was then removed, and water was found between the layers of lead. The paper under the lead appeared damp at the pump house end.

(8) Test of portion of cable between third cut and second cut, at second cut, after removal of some wet insulating paper—

First Core to sheath—1 megohm.
Second Core to sheath—1.25 megohm.
First Core to Second Core—450,000 ohms.

The joint in the cable at joint box B was then partly untaped, but no signs of breakdown appeared.

The cable was then cut through just on the pumphouse side of the joint B, at the fourth cut.

(9) Test of portion of cable between fourth cut and second cut, at second cut, after separation of tails at joint box—

First Core to sheath—2 megohms.

Second Core to sheath—2.5 megohms.

Third Core to sheath—3.5 megohms.

First to Second Core—4 megohms.

Second to Third Core—4 megohms.

Third to First Core—4 megohms.

(10) Test of portion of cable between third and fourth cuts, at third cut—

All six tests—Infinity.

Conclusion

From the above it seems clear that the area of low insulation was on the pumphouse side of the cable joint at joint box B due to ingress of moisture through the lead wrapping under the clamp, hence wetting some of the paper insulation of the cable. The cable was in a trench about 2 feet deep, which filled with water as the cable was dug up. In addition, a further head of about two feet of water, oil and foam had remained above the surface of the ground for some days after the fire.

The cable had been insulation-tested six months ago and was then in perfect condition.

It therefore appears possible that the decrease in insulation resistance had occurred since the fire. Removal of some of the wet paper, and separation of the cores, had the effect, it will be noted, of improving the insulation values, and leaves no room for doubt as to the location of the area of low insulation. There was however, no sign of any breakdown having occurred."

APPENDIX 6

CIRCULAR LETTER.

HOME OFFICE.

WHITEHALL.

Please quote:

845194/1.

29th May, 1940.

Gentlemen,

I am directed by the Secretary of State to inform you that he has had under consideration the question of the arrangements to be made for local fire brigades to afford assistance in the event of a fire occurring at an explosive or ammunition factory or large oil depot.

It is recognised that in dealing with any such fire it would be necessary for any fire brigade attending to work in close co-operation with the management. Factory or depot managements are therefore advised to concert forthwith with the Chief Officer of the local fire brigade definite arrangements as to the procedure to be adopted in the event of fire breaking out which is beyond the scope of the factory's or depot's own apparatus or personnel.

In devising a scheme of co-operation with local fire brigades, it is most important that the factory or depot management should appoint a person on duty at the factory or depot who would be responsible for calling in the local fire brigade if a fire occurs which cannot be dealt with effectively by the factory or depot. If, because of the special risks at the factory or depot, it is undesirable that local brigades should enter the premises as they arrive, arrangements should be made with the Chief Officers concerned for a brigade or brigades attending to proceed to a pre-arranged rallying point until it can be definitely settled where they should get to work.

Rough plans of the premises should be supplied to the Chief Officer of the local fire brigade and also to other brigades which might be called in by him as reinforcements under the Fire Brigades Regional Orders. The plans should

show the location of all points of water supply and the approaches to the factory or depot.

I am also to draw your attention to section 14 (3) of the Fire Brigades Act, 1938, which deals with the control of fire brigade operations at fires. That Section provides that the Senior Officer present of the fire brigade maintained for the Borough or District in which the fire originates shall have full charge of the operations for the extinction of the fire, unless under any scheme or arrangement made in pursuance of the Fire Brigades Act there is some different provision, in which case the other person so designated shall have the charge. The object of this latter exception is to provide for special cases, e.g. where, in the case of fire at an explosive works or oil depot which constitutes a fire risk of a special character, it may be preferable for the operations at the fire to be in the control of the Chief Officer of the factory or depot brigade or one of the staff with the requisite technical knowledge of the plant and the manufacturing processes carried on. The desirability of taking advantage of these statutory powers is a matter which might well be discussed by the factory or depot management with the local fire authority, in special cases, as part of the concerted arrangements referred to above.

It should be borne in mind that if reinforcements at a fire are to be called for under the Fire Brigades Regional Orders, the channel through which such additional assistance is to be obtained is the Chief Officer of the local fire brigade, who is in possession of full particulars of the regional reinforcement Scheme.

A copy of this letter has been sent to the Chief Officer of the local fire brigade for your district.

I am,

Gentlemen,

Your obedient Servant.

(Signed) W. M. GOODE.

APPENDIX 7

COPY.

H.O. 225/1.

Reg. No. 32

Note:

THIS LICENCE IS NOT TRANSFERABLE

PORT OF BRISTOL AUTHORITY

PETROLEUM (CONSOLIDATION) ACT, 1928

PETROLEUM SPIRIT LICENCE

Pursuant to the provisions of the Petroleum (Consolidation) Act, 1928, and of any Orders in Council thereunder in force for the time being, the Council of the City and County of Bristol as the Harbour Authority hereby grant licence to The Regent Assets Co., Ltd., having their registered office at Salisbury House, Finsbury Circus, London, E.C.2 (hereinafter referred to as "The Licensee") for the period of twelve calendar months from the 1st day of April, 1948, to keep 12,000,000 gallons of petroleum-spirit on the premises situate at the Royal Edward Dock, Avonmouth, within the jurisdiction of the Harbour Authority (which premises are coloured red on the plan attached hereto) subject to the conditions following, that is to say:—

1. Such petroleum-spirit shall be kept only in the manner and at the place or places hereinafter specified, viz., in the storage tanks, small tanks in the filling shed and in securely closed metal vessels at the Installation at the Royal Edward Dock, Avonmouth, and as shown red on Plan* No. L/2016 attached hereto.

2. The place of storage aforesaid shall be in all respects kept and maintained in the same condition as it was in when last inspected by the Docks Engineer or his duly authorised agent before the granting of this Licence.

* Plan not shown in this Report.

3. Due precaution shall at all times be taken for the prevention of accident from fire and in no circumstances shall fire or artificial light as will ignite inflammable vapour be permitted within, or nearer than 100 ft. of the openings of buildings, workrooms or places where petroleum-spirit is kept or used unless prior written approval is given by the Docks Engineer and such conditions as may be imposed by him are observed.

4. Petroleum-spirit shall not be allowed to enter any inlet or drain communicating with the public sewer; and every such inlet shall be provided with an intercepting chamber or trap so constructed as to prevent effectually the accidental discharge into a drain of petroleum-spirit.

5. No substance other than petroleum-spirit shall be deposited or kept in the place prescribed in the first condition of this Licence.

6. Except in so far as is specially provided for in the first condition of this Licence all petroleum-spirit kept upon the premises shall be exclusively contained in strong metal vessels, the openings of which are covered with fine wire gauze and fitted with screw caps and with secure taps so constructed and connected as to prevent leakage or the escape of vapour; and such vessels and taps shall be kept in thoroughly good order.

7. There shall be attached to, or, where that is impracticable, displayed near, every vessel containing the petroleum-spirit, a label, showing in conspicuous characters, the words "PETROLEUM-SPIRIT" and the words "HIGHLY INFLAMMABLE" and (i) in the case of petroleum-spirit kept, the name and address of the consignee or owner; (ii) in the case of petroleum-spirit sent or conveyed, the name and address of the sender; (iii) in the case of petroleum-spirit sold or exposed or offered for sale, the name and address of the vendor.

8. Petroleum-spirit shall be conveyed to or from the licensed premises only in closed vessels so constructed as to be entirely free from leakage.

9. No petroleum-spirit shall be conveyed to or from the licensed premises in a vehicle in which gunpowder or other article likely to cause fire or explosion shall be also carried.

10. No match or other explosive or inflammable thing shall be allowed, and no person shall be permitted to smoke at any time in any building or place where petroleum-spirit is kept or used under this Licence.

11. The vessels containing petroleum-spirit shall be opened upon the licensed premises only at or immediately adjoining the place of storage, and only for such time as is necessary for the drawing off of the petroleum-spirit. During such drawing off every reasonable precaution shall be adopted for preventing the escape of petroleum-spirit or the vapour therefrom.

12. All petroleum-spirit received upon the premises shall at once be taken to the place of storage; and all petroleum-spirit taken from the place of storage for delivery or otherwise shall at once be removed from the premises.

13. The licensed premises shall at all times be watched and guarded by a competent person or persons.

14. The Licensee shall take effectual precautions for preventing unauthorised persons and all persons under the age of fifteen years from obtaining access to the place of storage.

15. Petroleum-spirit shall not be kept or used in any part of the premises other than as specified in this Licence.

16. Buildings or workroom in which petroleum-spirit is kept or used shall at all times be thoroughly ventilated into the external atmosphere.

17. The vessels containing petroleum-spirit placed in the store shall be so arranged as not to obstruct any ventilation opening.

18. A shovel and a sufficient quantity of fine sand, or other form of fire extinguisher approved by the Docks Engineer or his duly authorised agent, shall be kept in or near the store and in any workroom or place where

petroleum-spirit is used, and a sufficient quantity of sand shall be spread round every tank or vessel containing any petroleum-spirit for the purpose of absorbing any leakage.

19. The Docks Engineer or his duly authorised agent shall at all times be allowed free access to the premises for the purpose of ascertaining if the conditions attached to this Licence are properly observed and of obtaining samples of petroleum-spirit on payment therefor. The Licensee shall give any assistance which such Officer may require.

20. No carriage, wagon, cart, dray or other such vehicle, however drawn or propelled shall be used for the carriage of petroleum-spirit from place to place after notice has been given by the Docks Engineer or his duly authorised agent that such vehicle is considered unsatisfactory for such purpose.

21. No supplies of petroleum-spirit shall be received after one hour after sunset.

22. Every vehicle used for the conveyance of petroleum-spirit, whilst standing in or near the licensed premises or whilst conveying petroleum-spirit, shall be provided with a suitable and efficient fire extinguisher, and a responsible person conversant with the use of such fire extinguisher shall be in attendance upon each vehicle whilst carrying petroleum-spirit and due precaution shall be taken to prevent unauthorised persons interfering with the petroleum-spirit being so conveyed or with the vehicle used for the conveyance of the same.

23. Doors, or other means of access to the mechanism of any petrol pump on the licensed premises shall at all times when the pump is not in use be kept closed and locked.

24. All empty vessels which have contained petroleum-spirit shall at all times be kept securely closed except during such time as such vessels are undergoing repair.

25. All empty vessels which have contained petroleum-spirit shall be kept within the place of storage (premises described in the lease to the Company referred to in Condition 28 below).

26. All persons employed directly or indirectly by the Licensee having access to the premises hereinbefore mentioned shall act in accordance with and observe the several conditions of this Licence.

27. The Licensee shall forthwith post and cause to be kept posted on the premises to which this Licence relates in such form and in such position as to be easily read by the persons employed in or about the said premises a notice setting out the conditions of this Licence, and the Licensee shall use his best endeavours to cause the said conditions to be properly understood by the persons employed in or about the said premises.

28. This Licence does not authorise the keeping or storing of carbide of calcium.

29. Nothing in this Licence or in the foregoing conditions is intended or shall be deemed to absolve the Licensee or other person or persons from liability to observe and carry out any conditions, requirements or other provisions contained in any Act of Parliament, Order in Council, General Regulation of the Board of Trade or other Government Department, or By-Law or Regulation made by the Harbour Authority (or in the lease with the Company dated the 21st day of June, 1934).

30. Throughout this Licence and the conditions attached thereto the expression "petroleum-spirit" shall be deemed to include as well as petroleum-spirit any substance containing petroleum-spirit and any product or residue derived from petroleum-spirit.

Give under my hand on behalf of the said Harbour Authority this second day of April, 1948.

(Sgd.) W. G. NEALE,
Secretary,
Bristol Docks Undertaking.

The following extracts from the Petroleum (Consolidation) Act, 1928, should be carefully read.

Section 1.

(1) Subject to the provisions of this Act, petroleum-spirit shall not be kept unless a petroleum-spirit licence is in force under this Act authorising the keeping thereof and the petroleum-spirit is kept in accordance with such conditions, if any, as may be attached to the Licence. . . .

(2) The occupier of any premises in which petroleum-spirit is kept in contravention of this section shall be liable on summary conviction to a fine not exceeding twenty pounds for every day on which the contravention occurs or continues, and the court before whom any person is convicted under this sub-section may order that the petroleum-spirit in respect of which the contravention occurs, and any vessel in which it is contained be forfeited or otherwise dealt with in such manner as the court think fit.

(3) If any person to whom a petroleum-spirit licence is granted contravenes any condition of the licence, he shall be liable on summary conviction to a fine not exceeding twenty pounds for every day on which the contravention occurs or continues.

Section 2.

(3) A local authority may attach to any petroleum-spirit licence such conditions as they think expedient as to the mode of storage, the nature and situation of the premises in which, and the nature of the goods with which petroleum-spirit is to be stored, the facilities for the testing of petroleum-spirit from time to time, and generally as to the safe-keeping of petroleum-spirit.

(4) Where conditions to be observed by persons employed are attached to any petroleum-spirit licence, the occupier of the premises to which the licence relates shall cause to be kept posted on the premises, in such form and in such position as to be easily read by the persons employed on the premises, a notice setting out those conditions, and

(a) If the occupier of any premises fails to comply with the foregoing requirements of this sub-section, he shall be liable on summary conviction to a fine not exceeding five pounds for every day on which the failure occurs or continues; and

(b) If any person pulls down, injures, or defaces any notice posted in accordance with the requirements of this sub-section, he shall be liable on summary conviction to a fine not exceeding five pounds; and

(c) If any person employed contravenes any condition of which notice has been given in accordance with the requirements of this sub-section, he shall be liable on summary conviction to a fine not exceeding five pounds.

Section 5.

(1) Subject as hereinafter provided where any petroleum-spirit—

(a) Is kept at any place; or

(b) is sent or conveyed between any two places in Great Britain; or

(c) is sold or exposed or offered for sale;

there shall be attached to, or, where that is impracticable, displayed near, the vessel containing the petroleum-spirit, a label shewing, in conspicuous characters, the words—

“ PETROLEUM SPIRIT ” and the words “ HIGHLY INFLAMMABLE ”

and—

(i) in the case of petroleum-spirit kept, the name and address of the consignee or owner;

(ii) in the case of petroleum-spirit sent or conveyed, the name and address of the sender;

(iii) in the case of petroleum-spirit sold or exposed or offered for sale, the name and address of the vendor;

(2) Any person who keeps, sends, conveys, sells or exposes or offers for sale any petroleum-spirit in contravention of this section shall be liable on summary conviction to a fine not exceeding five pounds and the court before whom any person is convicted in respect of any such contravention may order that the petroleum-spirit, in respect of which the contravention occurs, and any vessel in which it is contained be forfeited or otherwise dealt with in such manner as the court thinks fit.

Section 13.

(1) Whenever any accident which occasions loss of life or personal injury occurs by explosion or by fire in or about or in connection with any licensed premises the occupier of the premises shall, if the explosion or fire involved petroleum-spirit, forthwith send or cause to be sent to the Secretary of State notice of the accident and of the loss of life or personal injury. A notice of any accident of which notice is sent in pursuance of this section need not be sent to any inspector of factories.

(2) Where, in, about, or in connection with any ship or vehicle on which petroleum-spirit is being conveyed or loaded or from which petroleum-spirit is being unloaded, any accident which occasions loss of life, or personal injury occurs by explosion or by fire, the owner or the master of the ship or vehicle shall, if the explosion or fire involved petroleum-spirit, forthwith send or cause to be sent to the Secretary of State notice of the accident and of the loss of life or personal injury, but this provision shall not apply where the petroleum-spirit carried or loaded, on, or unloaded from the ship or vehicle is or was for use only on that ship or vehicle or in any case in which such notice as aforesaid is otherwise by law required to be sent to some government department.

(3) Every such occupier, owner, or master as aforesaid who fails to comply with any of the provisions of this section shall be liable on summary conviction to a fine not exceeding twenty pounds.

Section 23.

In this Act, unless the context otherwise requires, the following expressions have the meanings hereby respectively assigned to them (that is to say):—

"Petroleum" includes crude petroleum oil made from petroleum or from coal, shale, peat or other bituminous substance, and other products of petroleum.

"Petroleum-spirit" means such petroleum as when tested in the manner set forth in part II of the Second Schedule to this Act gives off an inflammable vapour at a temperature of less than seventy-three degrees Fahrenheit.

H.O. 225/C.

EXTRACT FROM THE PETROLEUM (CONSOLIDATION) ACT, 1928

First Schedule

Rates of Fees payable in respect of Licences to keep Petroleum-spirit

	<i>Rates per annum of fees payable</i>	
	£	s. d.
In respect of a licence to keep a quantity—		
Not exceeding 100 gallons	5	0
Exceeding 100 gallons, not exceeding 500 gallons	10	0
Exceeding 500 gallons, not exceeding 1,000 gallons	15	0
Exceeding 1,000 gallons, not exceeding 5,000 gallons	1	0 0
Exceeding 5,000 gallons, not exceeding 10,000 gallons	2	0 0
Exceeding 10,000 gallons, not exceeding 20,000 gallons	3	0 0
Exceeding 20,000 gallons, not exceeding 50,000 gallons	4	0 0
Exceeding 50,000 gallons	5	0 0

Note: In the case of a solid substance for which by virtue of an Order in Council made under Section nineteen of this Act, a licence is required to be granted under the said Section the fee payable under the Schedule shall be calculated as if ten pounds weight of the substance were equivalent to one gallon.

RENEWAL OF LICENCE

This licence is hereby renewed so as to be in force for the period of twelve months from the 1st day of April, 1949.

(Sgd.) W. G. NEALE,
Secretary,
Bristol Docks Undertaking.

RENEWAL OF LICENCE

This licence is hereby renewed so as to be in force for the period of twelve months from the 1st day of April, 1950.

(Sgd.) W. G. NEALE,
Secretary,
Bristol Docks Undertaking.

RENEWAL OF LICENCE

This licence is hereby renewed so as to be in force for the period of twelve months from the 1st day of April, 1951.

(Sgd.) W. G. NEALE,
Secretary,
Bristol Docks Undertaking.

RENEWAL OF LICENCE

This licence is hereby renewed so as to be in force for the period of twelve months from the day of , 19 .

Secretary,
Bristol Docks Undertaking.

RENEWAL OF LICENCE

This licence is hereby renewed so as to be in force for the period of twelve months from the day of , 19 .

Secretary,
Bristol Docks Undertaking.

RENEWAL OF LICENCE

This licence is hereby renewed so as to be in force for the period of twelve months from the day of , 19 .

Secretary,
Bristol Docks Undertaking.

PORT OF BRISTOL AUTHORITY

SPECIAL CONDITIONS FOR ELECTRICALLY OPERATED PETROL PUMPS

All electrically operated petrol pumps must comply with the following special conditions as laid down in Home Office Circular 198/1947, dated 25th September, 1947.

The following conditions shall apply to electrically operated pumps for the delivery of petrol:—

(a) **Pump Motors.** The enclosures of pump motors shall be of flame proof construction.

(b) **Switchgear.** The casings of all switches, contactors or relays situated within or on the pump equipment housing, and whether used for power, lighting or other purpose, shall be of flame proof construction.

(c) **Lighting Fittings.** Lighting fittings situated within or partly within the pump equipment housing, shall be of flame proof construction. Lighting fittings mounted on the outside of the pump equipment housing shall be of an enclosed design in which the lamp is protected by a well glass or other glass sealed to the body of the fitting by a gasket so as to resist the ingress of petroleum spirit vapour into the fitting.

(d) **Wiring.** All cables within the pump equipment housing shall be enclosed in heavy gauge galvanised solid-drawn steel conduit. The ends of the conduit shall be screwed into the flame proof apparatus and into conduit fittings, where the latter are used, so as to engage the threads by at least one inch, the joints to be treated against ingress of water. Alternatively, mineral-insulated copper-sheathed cable with appropriate flame proof fittings may be used.

(e) **Conduit Fittings.** All conduit fittings within the pump equipment housing, such as inspection bends and joint boxes, shall be of flameproof construction and galvanised.

(f) **Connection of Supply Cables.** Connection of electricity supply shall be made to the flame proof part of the installation within the pump equipment housing by means of wiring enclosed in heavy gauge galvanised solid-drawn screwed steel conduit, the end of which within the housing shall engage the termination provided by the pump manufacturer by not less than one inch. The conduit should preferably be in an unbroken length within the base of the pump, but if the conduit fittings are necessary because of the nature of the conduit run, they should be of flame proof type as (e) above. Joints shall be treated against the ingress of water. Alternatively, mineral-insulated copper-sheathed cable with appropriate flame proof fittings may be used. Conduit or copper sheath shall not be used as one of the conductors supplying the apparatus, i.e., all conductors of the supply wiring shall be insulated.

(g) **Earthing.** The metal enclosures of all apparatus and the conduit shall be efficiently earthed.

(h) **Electrical Protection.** The supply circuits of each pump shall be separately protected by fuses or circuit-breakers, set to operate at a current value as near as practicable to the normal current taken by the apparatus. The fuses or circuit-breakers shall not be situated within or on the pump equipment housing.

The term "flameproof", applied to electrical apparatus and used in the conditions shall denote apparatus which is certified to Group II standard by the Testing Authority (The Ministry of Fuel and Power) in accordance with British Standards Nos. 229 and 889 as appropriate and which is marked with the flame proof certificate number.

(Sgd.) W. G. NEALE,
Secretary.

CROWN COPYRIGHT RESERVED

PRINTED AND PUBLISHED BY HER MAJESTY'S STATIONERY OFFICE

To be purchased from

York House, Kingsway, LONDON, W.C.2 423 Oxford Street, LONDON, W.1
P.O. Box 569, LONDON, S.E.1

13a Castle Street, EDINBURGH, 2 1 St. Andrew's Crescent, CARDIFF
39 King Street, MANCHESTER, 2 Tower Lane, BRISTOL, 1
2 Edmund Street, BIRMINGHAM, 3 80 Chichester Street, BELFAST

or from any Bookseller

1952

Price 2s. 0d. net

PRINTED IN GREAT BRITAIN

S.O. Code No. 34-350